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INSECT AND FUNGOUS ENEMIES OF THE GRAPE EAST OF THE ROCKY MOUNTAINS.

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U. S. DEPARTMENT OF AGRICULTURE,
Washington, D. C., March 6, 1907.

SIR: We have the honor to transmit herewith a paper entitled "Insect and Fungous Enemies of the Grape East of the Rocky Mountains," prepared by Mr. A. L. Quaintance, of the Bureau of Entomology, and Dr. C. L. Shear, of the Bureau of Plant Industry.

This bulletin treats of the principal insect and fungous enemies of the American varieties of grapes, giving the most successful methods of treatment at present known. It first states the nature of the insect enemies and the means of controlling them, then discusses the fungous parasites, including treatment, and in conclusion gives an account of spraying apparatus, with directions for applying spray mixtures. The reason for the joint publication arises from the fact that the remedial measures used in combating the insects and the fungous parasites are of such a nature that the applications can be combined and thereby result in a great reduction in cost of time and labor. We recommend the publication of this paper as a Farmers' Bulletin.

Respectfully,

L. O. HOWARD,
Chief of the Bureau of Entomology.
B. T. GALLOWAY,
Chief of the Bureau of Plant Industry.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INSECT AND FUNGOUS ENEMIES OF THE GRAPE EAST OF THE ROCKY MOUNTAINS.

INSECT ENEMIES.

All of the important insect enemies of the grape in the United States at the present time are native American species, feeding originally, as they do at the present day, on various wild species of grapes and related plants. With the planting of vineyards and the extension of the grape-growing industry many species attacked also the cultivated varieties, and some few have become exceedingly troublesome pests. Perhaps no horticultural crop so well illustrates the serious loss which may result from native species of insects attacking cultivated varieties of their natural wild food plants as does the grape. As a rule, varieties with a preponderance in parentage of the European grape (*Vitis vinifera*) are not vigorous growers in the Middle and Eastern States and suffer to a greater degree from insect attack than varieties with parentage of American vines. But these latter are not exempt and, with the exception of one or two insects, are equally subject to attack. The principal exception to be noted is the grape phylloxera, an aphide or "plant louse" which infests the roots and also the leaves of the grape and is especially injurious to vinifera or European varieties. Several species of American grapes and some of their hybrids and varieties, and other kinds to a less degree, are resistant to attack from this insect, and these are used as grafting stock for vinifera varieties in California and Europe, where the insect has been and is especially troublesome. It has been suggested that certain species or varieties of American grapes are resistant to the grape root-worm also, and although there is no evidence bearing on the question, the matter is of sufficient importance to warrant careful investigation.

Of the two hundred or more species of insects known to feed upon the grape in the United States, those treated herein include, with the exception of the phylloxera, those of principal importance, namely, the grape root-worm, grape berry moth, grape curculio, grape leaf-hopper, grape leaf-folder, grapevine flea-beetle, and rose-chafer. Grape insects are not less amenable to treatment than insect pests of other fruit crops, and the vineyardist may confidently expect to be

able to keep them under control by the application of the remedies herein recommended. As the reader will learn in the following pages, the principal insect and fungous enemies of the grape may be controlled with material reduction of cost by timely and thorough applications of a combined insecticide and fungicide used in the form of a liquid spray. As in the control of most other insect pests, cultural methods are of very great importance. Vines kept in a vigorous, healthy condition by cultivations and fertilization are much better able to withstand insect attack than those grown under conditions of neglect.

THE GRAPE ROOT-WORM.

The grape root-worm (*Fidia viticida* Walsh), as the name indicates infests the roots of the grape, devouring more or less completely the smaller roots and rootlets and eating pits or burrows into the outer portion of the larger roots. It is the larva of a small, hairy, chestnut-brown beetle which makes its appearance in vineyards at about the close of the blooming period of such varieties of grapes as Concord, Niagara, Catawba, and Delaware. The beetles feed freely on the upper surface of the leaf, eating a series of patches or holes through to the lower surface, thus producing characteristic chain-like feeding marks, as shown in figure 1 at *h*, by which their presence in vineyards may be readily detected. The injury to the foliage, however, is quite unimportant compared to the work of the larvæ on the roots. When the larvæ are abundant the vines may be killed in the course of a season or two, but usually the plants will live longer, though making but a feeble growth and failing to produce profitable crops. The death of vines or the gradual failure of a vineyard should call for an examination of the foliage for the feeding marks of the beetles and of the roots for the work of the larvæ on these parts.

Distribution and Destructiveness.

The grape root-worm, or grapevine Fidia, is without doubt a native species, feeding originally on wild grapes, as it does at the present time. In addition to cultivated varieties of grapes it has also been recorded as feeding on the Virginia creeper (*Ampelopsis quinquefolia*) and the American red-bud (*Cercis canadensis*). In the literature of the species it is said to occur in Iowa, Missouri, Arkansas, Illinois, Kentucky, Ohio, New York, and New Jersey. In 1892 Doctor Horn gave the distribution of the insect as from the "Middle States to Dakota, Florida, and Texas." According to the records of the Bureau of Entomology the insect occurs in New York, Pennsylvania, Virginia, North Carolina, Ohio, Illinois, Kentucky, Missouri, Mississippi, Texas, and California. The species is therefore widely distributed in the Mississippi Valley and in the Eastern States, and occurs also in California.

This insect first came into notice as a pest of cultivated grapes in 1866, in Kentucky, by reason of injury to the foliage caused by the adults or beetles. This attack was the subject of a short note by Mr. B. D. Walsh in the Practical Entomologist.[a] The following

[a] Practical Entomologist, Vol. 1, p. 99 (1866).

year the species was described by Mr. Walsh and given the name it still bears.[a] Riley in 1879, in his First Report on the Injurious Insects of Missouri, regarded the insect as one of the worst pests of the vine in that State, where it occurred abundantly and was miscalled the rose bug (*Macrodactylus subspinosus*). In 1893 and subsequently the insect became very injurious in vineyards in northern Ohio, and was carefully investigated by Prof. F. M. Webster,[b] who showed that the larvæ or grubs of the beetle fed upon the roots of the vine, causing much more serious damage than was caused by the beetles in feeding upon the foliage. In 1900 the insect was discovered by Professor Slingerland[c] to occur in injurious numbers in vineyards in the Chautauqua grape belt in western New York, and during the three or four years following was carefully studied by him and also by Dr. E. P. Felt, and effective remedial measures were devised by extensive practical experiments. At the present time the grape root-worm continues to be a pest of importance in the vineyards of northern Ohio, the Erie grape belt in Pennsylvania, and the Chautauqua region of western New York. Throughout these regions the insect on the whole seems to be diminishing in importance, in part through natural agencies but more especially following adequate cultivation of vineyards and the use of sprays.

The insect thrives best in vineyards which are neglected; in the absence of cultivation and timely spraying it is likely to become a serious pest in any vineyard throughout its range of distribution. This is especially the case in light, sandy soils and in regions where grape growing is a considerable industry.

Description and Life History.

Adult.—The beetle, or parent insect of the grape root-worm, is shown enlarged at *a*, figure 1. It is about one-fourth of an inch long, rather stout, with long legs, the body brownish in color and covered with grayish white hairs. The adults make their appearance in vineyards beginning about the close of the blooming period of the vines, which in the New York, Pennsylvania, and Ohio grape districts, during normal seasons, will be from about the 15th to about the 20th of June. The great majority of beetles will appear during the latter part of June and the first two or three weeks of July, though a few will be coming out during the latter part of July, and stragglers may appear for a month or six weeks later. In a given locality there will be some variation in the time of appearance, which will be earlier on light, sandy soils or warmer locations and later on heavier soils. In the course of a few days after emergence the beetles begin to feed, eating rows of holes in the upper surface of the leaf, as shown in figure 1 at *h*. After some days of feeding the females begin to deposit eggs, the number for an individual female varying considerably. Doctor Felt[d] has obtained egg-laying records of 156, 342, and 902 eggs, respectively, for three individuals, and the averages per insect from three lots of insects kept under observation were 141, 192, and 488, respectively, the average for the

[a] Practical Entomologist, Vol. 2, pp. 87–88 (1867).
[b] Bul. 62, Ohio Agrl. Exp. Station (1895).
[c] Bul. 184, Cornell Univ. Agrl. Exp. Station (1900).
[d] Bul. 19, Office State Ent. of N. Y., p. 20 (1903).

entire number being nearly 175 eggs per female. According to the same writer, about 45 per cent of the eggs of the individuals above mentioned were deposited during the first two weeks, and 73 per cent of the entire number were deposited during the first month after emergence. Beetles are to be found on the vines during a considerable period, owing to their longevity and to an irregularity in emergence, though, as stated, oviposition is largely done during the three or four weeks fol-

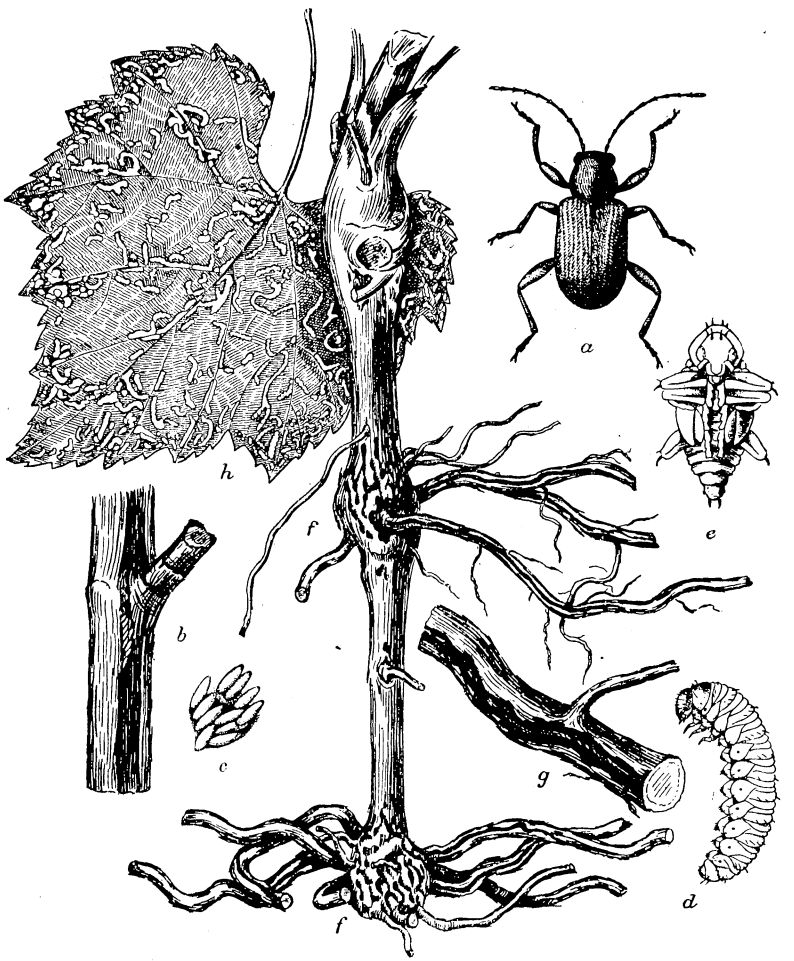

FIG. 1.—Grape root-worm (*Fidia viticida*): *a*, Adult or beetle; *b*, eggs on cane, about natural size; *c*, eggs, enlarged; *d*, full-grown larva; *e*, pupa; *f*, *f*, *g*, roots of grape, showing injury by larvæ; *h*, grape leaf, showing characteristic chain-like feeding marks made by beetles. *a*, *c*, *d*, *e*, Much enlarged; *b*, *g*, about natural size; *f*, *h*, reduced.

lowing emergence. Upon being disturbed many of the beetles will lose their hold upon the vines and fall to the ground in their efforts to escape detection. Advantage may be taken of this fact, as explained later, to collect the insects from the vines by jarring.

Egg.—Eggs are deposited in patches usually from 25 to 40, sometimes less, but rarely more, according to Slingerland, mostly under the

bark of last year's wood, and may occur quite generally over the canes, some quite near to the upper wire of the trellis. As stated by Professor Webster[a], 700 eggs were found on a single vine, and 225 eggs from a section of a cane but 16 inches long. The eggs are nearly cylindrical in shape, tapering at each end; whitish when first laid, but soon becoming yellowish in color. The eggs are about one-twenty-fifth of an inch in length, and more or less concentrically arranged in patches. From 9 to 12 days are required for the eggs to hatch. See figure 1, at *b* and *c*, showing eggs on grape cane and more enlarged.

Larva.—On hatching, the larvæ drop to the ground. At this time they are about one-seventeenth of an inch in length, and from their small size are readily able to find their way through the soil. Although the powers of locomotion and endurance of the young larvæ are considerable, to enable them to overcome difficulties in reaching their food, many doubtless fail to do so and perish. When established on the roots, however, the grubs feed freely and grow rapidly. By fall the majority of them will be full-grown or nearly so. Upon the approach of cold weather they descend into the earth several inches, a few as much as a foot below the surface, and here construct oval earthen cells in which they pass the winter. With the approach of warm weather the larvæ ascend to a point near the surface, the immature ones completing their growth, and the pupal stage is entered mostly from about 2 to 3 inches below the surface of the soil and within a radius of 1½ to 2 feet from the base of the vine. The full-grown larva is about five-eighths of an inch long, the body whitish, resting in a curved position. The head is yellowish brown in color, with a transverse diameter somewhat less than that of the body. The spiracles or breathing pores along each side are well marked, varying from light to yellowish brown in color. As shown in figure 1, at *d*, the insect in this stage resembles in miniature one of the common white grubs, from which it may be distinguished by the dark food material in the abdomen of the latter.

Pupa.—The full-grown larva prepares an earthen cell, within which it shortly changes to the pupa or "turtle" stage. In this condition the insect is soft and helpless, and the earthen cells are readily broken open and the pupæ crushed or otherwise killed by stirring the soil. As stated, the majority of the larvæ pupate about 2 or 3 inches below the surface of the ground, and this makes possible their destruction in large numbers by timely cultivations, as will be explained under the discussion of remedies. Pupation is perhaps at its height just before the blossoms of the grape begin to open, but the vineyardist may determine the period with exactness by examining the earth around the base of infested vines to ascertain the proportion of pupæ and larvæ present. Throughout the Chautauqua, Erie, and Ohio grape belts, during normal seasons, the insects will be in the pupal stage in maximum numbers during the first two or three weeks of June, varying somewhat, however, according to season and the character of the soil, being earlier on sandy and later on clay soils. The pupa is shown in figure 1 at *e*. It is from one-fourth to one-third of an inch long, whitish in color, but with a pinkish coloration about the head, thorax, and caudal portion. On the head, body, and appendages are spines, as shown in the figure. The pupal stage lasts about two weeks.

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[a] Bul. 62, Ohio Agrl. Exp. Station, p. 82 (1895).

Natural Enemies.

No parasitic enemies of the beetles, pupæ, or larvæ are recorded, but Professor Webster, in Ohio, has bred from the eggs two species of small hymenopterous wasps, namely, *Fidiobia flavipes* Ashm., and *Brachysticha fidiæ* Ashm., which he found to be doing most excellent work. The former parasite was also bred from eggs by Slingerland in New York State in 1905. Eggs are also attacked by two or three species of small mites, which destroy them by extracting the contents. The common little brown ant, *Lasius brunneus* var. *alienus*, also has been observed to feed upon the eggs, and several predaceous insects were found by Dr. E. P. Felt in the course of his field work in New York occurring in the soil infested by root-worms, and he thought it probable that these preyed upon this species. The beetles are no doubt fed upon by insectivorous birds and barnyard fowls, which also are known to feed upon the pupæ exposed in cultivating.

Treatment.

The insect may be fought in three important ways, namely, by poisoning the adults with an arsenical spray, jarring them from the vines onto sheets, and destroying the pupæ in the soil by cultivation.

Poisoning.—Shortly after emergence the beetles begin to feed upon the foliage, eating holes in the upper surface of the grape leaves, and hence may be readily poisoned. The use of poisons was recommended by Mr. Marlatt[a] in 1895, while Messrs. Slingerland and Johnson have shown by extensive practical experiments that the numbers of the pest may be greatly reduced in this way, and that poisoning in conjunction with cultivation, to be later mentioned, affords almost complete protection from its injuries. To be effective, however, the poisoned spray must be applied at the right times and with great thoroughness. The beetles begin to put in an appearance at about the close of the blooming period. Careful watch should be kept, and upon the first signs of the chain-like feeding marks on the leaves the vines should be thoroughly sprayed with a poison. A second application should be made in a week or ten days. These applications are intended to poison the newly emerged beetles during their first feeding and before they have deposited their eggs to any extent. If applications be delayed two or three weeks beyond the time indicated, a considerable percentage of the eggs will have been deposited, and the treatments will lose much of their value. Vineyardists having this pest to contend with should not make the mistake of spraying a little too late, but should have everything in readiness to begin applications upon the first appearance of the beetles. The beetles plainly avoid feeding on foliage sprayed with Bordeaux mixture or arsenate of lead, seeking the unsprayed leaves as much as possible. It is therefore especially necessary to make applications with great thoroughness, poisoning as nearly as possible the upper surface of every leaf, so that the beetles will be poisoned or forced to leave the vines for food. This desired thoroughness of treatment is not obtained as a rule by vineyardists, and greater care should be exercised in this work. In commercial vineyards the tendency will be to hurry through the

[a] Yearbook U. S. Dept. of Agriculture, 1895, p. 393.

work, covering 12 or 15 acres per day, using an insufficient amount of spray. With the spraying machinery in common use 7 to 8 acres per day is about all that may be covered with the desired thoroughness, and about 125 gallons of spray mixture should be applied per acre. In spraying for the grape root-worm, the poison should always be applied in Bordeaux mixture, which is used in the control of fungous diseases, as elsewhere considered in this bulletin. The several arsenical poisons which may be used are discussed on pages 26 and 27.

Destruction of beetles by jarring.—Doctor Felt has made extensive practical tests of jarring the beetles from the vines and catching them on sheets or special forms of catchers run under the plants or along the rows, and considers this to be an effective plan of controlling the pest, the jarring of the vines causing many of the beetles to fall in their efforts to escape detection. A sheet of canvas placed on the ground beneath the vines will serve to catch the beetles, but where work of this kind is done on a large scale special apparatus must be provided. There is room for considerable ingenuity in constructing catchers that will suit individual conditions. Concerning the value of jarring, Doctor Felt says:[a] "Our experience with collectors has demonstrated the practicability of catching the beetles, and we recommend this operation for all badly infested sections, and that the collecting be begun as soon as the beetles appear on the vines in any numbers, say where there are 12 or 15 on one. The operation should then be repeated at intervals of 5 to 7 days till the vines have been gone over two, three, or four times, depending somewhat on the number of insects which are captured. It will be found that it is much easier to catch the beetles on warm days, when it should be done, than in cool weather."

Destruction of pupæ by cultivation.—While the grape root-worm may be present in well cultivated vineyards, it is much less destructive than in vineyards which receive indifferent cultivation or total neglect. It has long been known that much good may be done in controlling insects which live underground by breaking open their pupal cells and crushing or otherwise killing the helpless pupæ. The importance of this work in the destruction of pupæ of the grape root-worm was first pointed out by Professor Slingerland in his studies of this pest in the Chautauqua grape belt, and subsequent experiments, confirmed by practical experience, have shown that this is a very important method of reducing the numbers of insects. After the larvæ have become full grown the great majority pupate but 2 or 3 inches below the surface of the soil, and mostly within a radius of 1½ or 2 feet from the base of the vine. In this stage the insects are quite helpless, and are killed in large numbers by a thorough breaking up of the soil around the base of the plants. As stated, the insect will be in the pupal stage in maximum numbers just before the period of blooming of the vines, and the cultivating should be done at this time. In the Ohio, Pennsylvania, and New York grape districts this will be about the middle of June, the time varying somewhat according to the character of the season and of the soil. The details of this work are very important and require explanation.

With the last cultivation in the fall the earth should be thrown to the vines on each side, forming a ridge along the row. The following

[a] Bul. 19, Office State Ent. of N. Y., p. 37 (1903).

spring the larvæ in making their way toward the surface of the soil to pupate will mostly work up in this ridge of earth, above the surface of the roots, and there enter the pupal stage. The cultivation of the vineyard in the spring should be so adjusted that this ridge of earth may be thrown away from the vines when most of the insects are in the pupal stage, as one of the regular cultivations. An implement known as a "horse-hoe," generally used in vineyards, may be employed to great advantage in this work; but as it is not practicable to remove the earth from immediately around the vine owing to danger of injury, it is necessary to follow the horse-hoe at once and remove the earth with a hand-hoe. The latter work is also done as a part of the regular vineyard treatment to keep down weeds and grass, and is timed so as to supplement the plowing with the horse-hoe for the insect. Following the removal of the ridge of earth from along the vines, it is well to keep the ground stirred at frequent intervals by means of a cultivator to further insure the destruction of the pupæ.

GRAPE BERRY MOTH.

The larva of the grape berry moth (*Polychrosis viteana* Clem.) infests the berry or fruit of the grape. The first generation attacks and webs together the grape clusters even before the blossoms open or soon after the grapes are set. Later-appearing larvæ bore into the green or ripening fruit and produce a purplish spot much resembling in appearance the injury due to the black-rot fungus, with which it is frequently confused. Within the fruit the larvæ feed on the pulp and seeds, passing from one grape to another, and several of these discolored and shriveling berries will often be found more or less webbed together with numerous particles of larval excrement, and sticky with exuding grape juice. Other insects attack the fruit of the grape, such as the grape-seed insect (*Isosoma vitis* Saunders), whose larvæ feed on the seeds, causing the berries to shrivel late in the summer, and the grape curculio (*Craponius inæqualis* Say), whose injury closely resembles that of the grape berry moth and is considered on a later page. But the principal cause of wormy grapes throughout the country is the larva of the species under consideration. Until recently it was thought that our grape berry moth was introduced from Europe many years ago. But Messrs. Slingerland and Kearfott have shown,[a] by careful study of this insect and related species, that the insect infesting American vineyards is quite distinct from the European form (*Polychrosis botrana* Schiff). These gentlemen have also shown that the American grape berry moth does not feed upon sumac, as was formerly held, and consider it very probable that the grape is the sole food of this species. This important fact greatly simplifies the question of its control, for if the species had other food plants vineyards would be reinfested from outside sources despite thorough treatments.

Distribution and Destructiveness.

The American grape berry moth occurs from Canada south to the Gulf and westward to California. It is very generally distributed over this area, and wherever the grape is grown it is more than likely to be

[a] Bul. 223, Cornell Univ. Agrl. Exp. Sta. (1904).

found. For a number of years the pest has been troublesome in Ohio vineyards, and also more or less locally in the Erie grape belt and in New York State. In 1902, according to Slingerland, it was destructive all through the Chautauqua grape belt, and was equally destructive through a large part of this area during the two succeeding years. At the present time the insect is destructive in individual vineyards here and there throughout the Chautauqua, Erie, and northern Ohio grape districts, causing a loss of many thousands of dollars annually. In some vineyards a loss of from 25 to 50 per cent of the crop is not infrequent, and in occasional instances the destruction of the fruit is practically complete.

Description and Life History.

The grape berry moth is small, the wings expanding not quite one-half inch. The general color is purplish brown, the wings with markings as shown in figure 2. Moths appear in the spring from hibernating pupæ, beginning about the time the shoots of the grape are pushing out, and continuing to emerge for some weeks. The earlier-appearing individuals deposit their eggs on the blossom clusters, while those coming out after the blossoms are shed oviposit on the clusters of young grapes.

The minute scalelike eggs of the first brood of moths are difficult to find, as at this time they are relatively scarce, but may be readily detected during summer as a glistening or whitish spot on the surface of the berries. The larvæ of the first generation feed upon the blossoms and small berries, webbing them together more or less and producing a more or less ragged bunch of grapes, or the cluster may be almost entirely destroyed. The capabilities of the larvæ for injury at this time are thus seen to be much greater than is the case with larvæ of the later broods, by which individual berries are attacked. The spring brood, however, is usually quite small; evidently there is a heavy mortality of the insect during the preceding fall and winter. About 3 weeks are required for a larva to complete its growth in summer, when it is about three-eighths of an inch in length, slender, light greenish to purplish in color, the head slightly bilobed, greenish above, and brownish in front, the thoracic feet blackish. When ready to pupate the larvæ go to the leaves, and a small portion is cut loose, except along one side, and bent over and fastened down with silk. Beneath this a thin, whitish, silken cocoon is spun, and in 3 to 4 days the larva changes to a light greenish brown pupa, from which the moth will emerge in some 12 to 14 days. The larva and curious cocoon and pupa are shown in figure 2, considerably enlarged. Moths of the second and later generations deposit their eggs on the developing grape berries, and the resulting larvæ bore into these, feeding on the pulp and seeds, the entrance point of the berry being marked by a purplish spot, which renders their detection quite easy. In the Chautauqua and Erie grape belts, and probably in northern Ohio, moths of the second generation will begin coming out and ovipositing about the first week or ten days of July, continuing for some weeks, the first and second broods overlapping. By this time the insects will have increased greatly in numbers, and the larvæ will be attacking almost exclusively the berries of the grape,

for which reason their work is much more conspicuous. Second-brood larvæ infest the grape during July and August, the later-appearing individuals probably not developing to moths but hibernating in the pupal condition. Many of the earlier-appearing insects of this brood appear to complete their life cycle, and moths develop, giving rise to a third generation of larvæ. According to the observations of Mr. Fred Johnson, of the Bureau of Entomology, at North East, Pa., practically a full third brood was produced during 1906. On September 7, according to this observer, larvæ one-third to one-half grown were very numerous, from 80 to 90 per cent of the berries in many clusters having been injured. Egg shells were very abundant on the fruit, which at this time was beginning to color. Many of the eggs had been parasitized by what is probably *Trichogramma pretiosa* Riley, a minute hymenopterous fly which oviposits in the eggs of many species of lepidopterous insects. A few larvæ were found in berries by Mr. Johnson as late as October 17, though practically all of the larvæ had left the fruit. They were found mostly on the leaves, which had already fallen to the ground, where

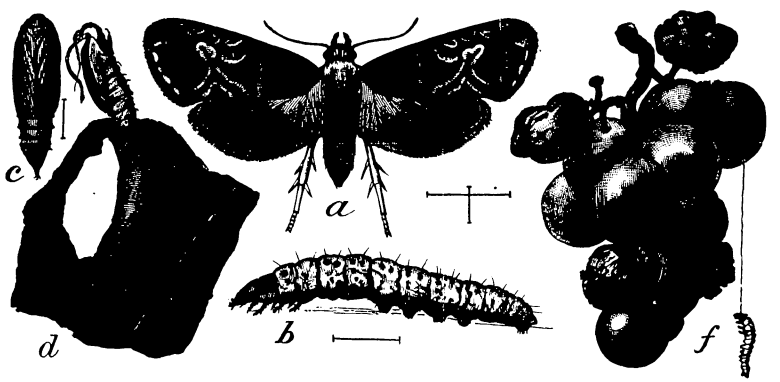

FIG. 2.—Grape berry moth (*Polychrosis viteana*): *a*, Adult or moth; *b*, larva; *c*, pupa; *d*, folded leaf, with pupa shell projecting from case cut from the leaf; *f*, grapes, showing injury, and larva suspended by its silk. All much enlarged, except *f*, somewhat reduced. (From Marlatt.)

it appeared the larvæ went to pupate, scarcely any being found on the foliage still attached to the vines. In the Middle and Southern States it is inferred that there may be each year three full broods, or perhaps more, but as yet the insect has not been studied in this territory.

Treatment.

Poisons.—The use of arsenical poisons against the first brood of the grape berry moth was recommended by Mr. Marlatt, of the Bureau of Entomology, in 1895.[a] Since this time the recommendation has been amply justified in the experience of numerous vineyardists, who, in connection with the fight against the grape root-worm, found that their early sprayings for this pest were also controlling the grape berry moth. Professor Slingerland reports an instance in which three timely applications of arsenate of lead, at the

[a] Yearbook, U. S. Dept. of Agriculture, 1895, p. 404.

rate of 10 or 12 pounds to 100 gallons of water, gave almost absolute protection during the rest of the season. Doctor Felt records [a] that the application of arsenate of lead along with Bordeaux mixture, for the grape root-worm, shortly after the blossoms had fallen and before the berries had grown to the size of a pea, resulted in a decrease of 50 per cent in the injury to fruit by the berry moth.

While definite experiments with poisons in the control of this pest appear not yet to have been reported,[b] the experience above given indicates their great usefulness. As would appear from the life history of the insect, most effective work may be done by destroying the first brood larvæ, which feed in the clusters of blossoms and berries. The first treatment should be made just before the blossoms are ready to open, and the second just after the blossoms have fallen. A third treatment in a week or ten days is also advisable in badly infested vineyards. In all these treatments special care should be exercised to force the spray well through the clusters of blossoms and young fruit. It will be noted that the second and third treatments for the grape berry moth will coincide with the first and second treatments for the grape root-worm, and the arsenicals recommended for that insect will be equally satisfactory for the grape berry moth. (See page 10.)

Picking infested berries.—This practice is often followed by vineyardists, and is especially directed against larvæ of the second brood. The infested spotted green berries, which are readily seen, should be carefully searched for and destroyed. This practice will lessen injury from a possible later brood, and if carefully followed would reduce the insects materially in the vineyard from year to year.

Bagging clusters.—Inclosing each cluster of grapes in a paper bag soon after the blossoms have fallen should protect them from injury from second and third-brood larvæ, and would also afford protection from the rose-chafer and from black-rot. This practice is especially useful in the small home vineyard.

Gathering fallen leaves.—The fact that the insect passes the winter in fallen leaves has led to the recommendation that these be raked up and burned. From Mr. Johnson's observations it would appear important to collect these early in the fall, as the pupæ are to be found mostly on the 10 or 15 per cent of leaves which fall first, and great care must be taken to collect those leaves more or less imbedded in the soil. After remaining on the ground for a while, probably many of the cocoons break off from the leaves and would thus not be collected with the leaves. It is probable also that many of the insects could be destroyed by covering the leaves with soil early in the fall.

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[a] Bul. 19, Office State Ent. of N. Y., p. 31 (1903).

[b] Since this article was written, definite experiments in spraying for the grape berry moth have been reported by Profs. H. A. Gossard and J. S. Houser in Circular 63 of the Ohio Agricultural Experiment Station. These gentlemen have shown that the insect may be largely controlled by three applications of an arsenical, with the addition of some form of soap to make the spray more adhesive, the time of making applications being practically as recommended above.

GRAPE CURCULIO.

The grape curculio (*Craponius inæqualis* Say) is one of the "snout beetles" belonging in the same family (Curculionidæ) as the so-called plum curculio. The parent beetle deposits her eggs in little cavities which she eats into the grapes, and the resulting larvæ feed upon the pulp and seeds, producing an injury quite similar to that done by the grape berry moth. The beetles cut small, rather characteristic holes in the grape leaves when feeding, and the berries often show a purplish coloration at the point punctured in egg-laying, as shown in figure 3. If infested berries be examined it will be readily possible to distinguish between the grape curculio and the grape berry moth, since the grubs of the former are whitish and quite destitute of legs, whereas the larvæ of the berry moth have well-developed legs, are greenish in color, quite agile, and likely to escape quickly upon being disturbed. See figure 4, showing, at *a*, an injured berry; *c*, the egg-cavity and egg beneath skin of grape; and *d*, an infested berry cut open.

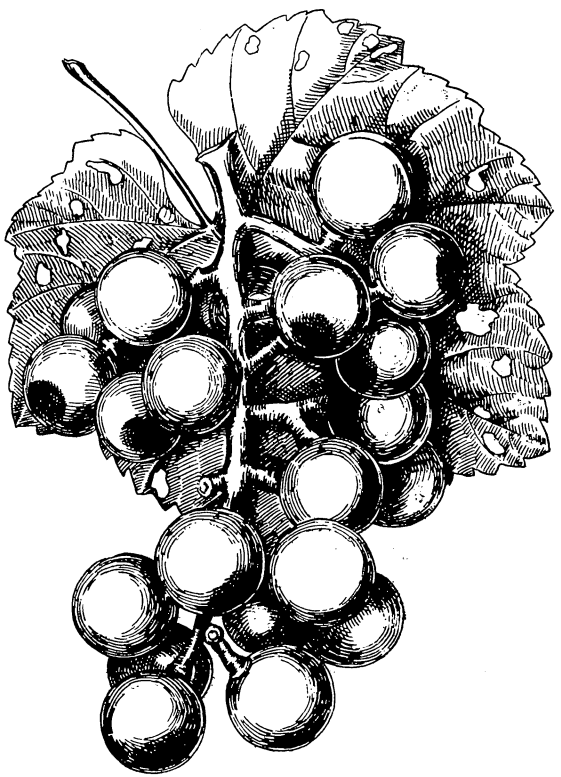

FIG. 3.—Grape leaf, showing feeding marks of grape curculio beetles, and bunch of grapes infested with larvæ. Somewhat reduced.

Distribution and Destructiveness.

The grape curculio is a native species, feeding originally on the wild grape, as it does at the present time. It has been recorded from Arkansas, Missouri, Tennessee, Kentucky, Illinois, Minnesota, Ohio, New Jersey, West Virginia, and North Carolina, and, according to Lintner, it probably occurs in New York State. The Bureau of Entomology has records of its occurrence in Pennsylvania, District of Columbia, West Virginia, North Carolina, and Nebraska. According to Le Conte and Horn, its distribution is "Middle, Southern, and Western States." The insect was described in 1830 by Thomas Say, but it first attracted attention as a grape pest in 1853 in the vicinity of Cincinnati, Ohio. An account of the species was given in 1867 by

B. D. Walsh, and comments were given on its injuries in Illinois, Ohio, and Kentucky. Injury by this species is more or less local and intermittent. Serious injury was reported by G. R. Wood in 1890 in the vicinity of Sandusky, and in 1891 Professor Webster found it very destructive in vineyards in Franklin County, Ark. For the past eight or ten years the grape curculio has been very destructive in many localities in West Virginia, destroying in many vineyards a large percentage of the crop. The species has been carefully studied by Mr. Fred E. Brooks, of the West Virginia Agricultural Experiment Station, and reported on in detail in Bulletin 100 of that institution. As shown by the experience in West Virginia and elsewhere, the species, under certain conditions, may become a very serious pest, ranking with the root-worm or berry moth. Mr. Brooks has shown that the insect is readily controlled with arsenical poisons and, as will be detailed later, (p. 47) treatments for the root-worm and berry moth will also keep this pest under control.

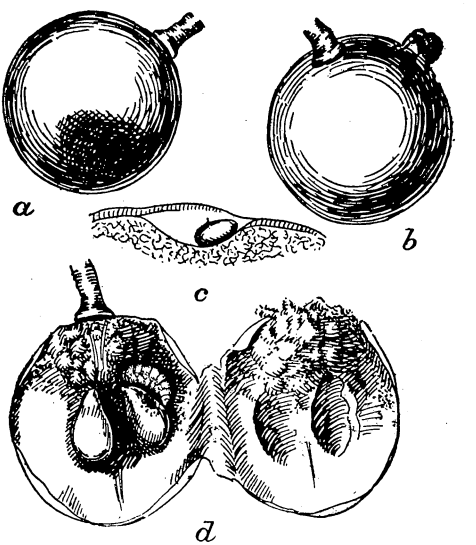

FIG. 4.—Work of grape curculio (*Craponius inæqualis*) in berry of grape: *a*, Berry from which grub or larva has emerged; *b*, adult or weevil ovipositing on berry; *c*, enlarged section of portion of berry, showing egg cavity and egg; *d*, injured berry, cut open and showing larva at work. *a*, *b*, *d*, Enlarged; *c*, highly magnified.

Life History and Habits.

The insect passes the winter in the adult or beetle stage, hiding under trash in and near vineyards, especially bordering woods. About the time in the spring that the grape is in bloom the beetles come from their hibernation quarters and for the first few days or a week are quite sluggish, but gradually become more active, feeding on the foliage of the grape until the berries are about one-fourth grown or of sufficient size to be suitable for receiving the eggs—according to Mr. Brooks, in 1905, covering a period of about 25 days. This habit of feeding on the exposed portions of the vines some 3 to 4 weeks before egg-laying permits of their ready destruction by arsenical poisons. Late in June, in the latitude of West Virginia, the females begin depositing eggs in the berries, excavating a cavity in which a single egg is placed. About 4 to 6 days, varying with the temperature, are required for the eggs to hatch, and the resulting larva burrows through the pulp, reaching the seed in 3 or 4 days, which is penetrated and the contents devoured. In 12 to 15 days the larva has become full grown and leaves the berry by eating a hole to the outside, falls to the ground and at once seeks a suitable place for pupation, as under stones, lumps of earth, or just below the surface of the soil. Here an earthen cell is made and the larva transforms to the pupa, the

adult beetle emerging in the course of 18 or 19 days, at first blackish in color with gray hairs, but soon becoming the normal brown color. In figure 5 the parent beetle is shown in dorsal view at *a*, and a side view at *c*; the larva or grub is shown in dorsal and ventral views at *d* and *e*, and the pupa at *f*.

The life cycle from egg to adult, as stated by Brooks for a large series of individuals, requires about 35 days. The new generation of beetles feed upon the foliage until fall, when they go into hibernation, appearing the following spring, as stated. Mr. Brooks determined the egg-laying capacity of 30 beetles, the minimum number deposited by one insect being 63, and the maximum 392, with an average of about 257, the oviposition period extending from June 22 to September 10, a period of 81 days. Oviposition is apparently most active during the first one or two weeks of July. The beetles of the hibernating and of the new generation overlap, and the earlier-

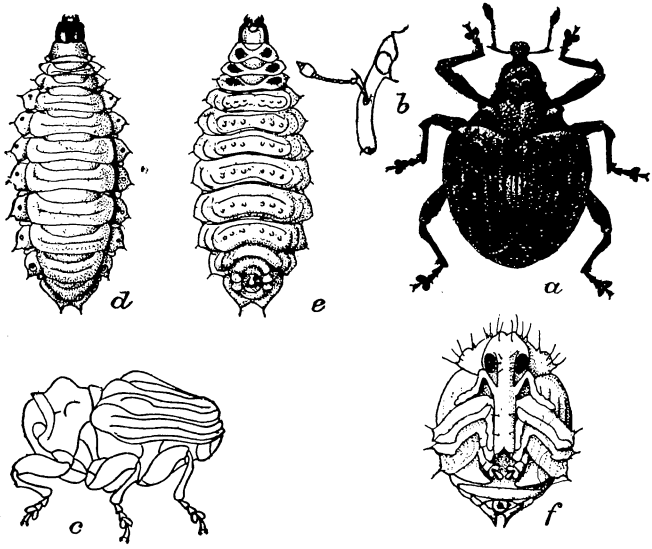

FIG. 5.—Grape curculio (*Craponius inæqualis*): *a*, Adult or beetle, from above; *b*, head, antenna, and beak of same, from side; *c*, adult, from side; *d*, larva, from above; *e*, same, from below; *f*, pupa, from below. All much enlarged.

appearing individuals of the latter may oviposit, but the resulting larvæ will mostly fail to reach maturity. Practically there is but one generation a year in the latitude of West Virginia, while in the South a second generation may occur, though it is considered doubtful.

Treatment.

Poisoning.—The beetles feed freely upon the foliage of the grape in the spring for several weeks before egg-laying begins and continue feeding in the fall after egg-laying ceases along with beetles of the new generation, and it is thus an easy matter to bring about their destruction by arsenical sprays. The treatments advised for the grape berry moth and root-worm, with perhaps an additional treatment 2 or 3 weeks later, will practically control the insect.

Bagging.—Fruit may also be well protected by bagging the clusters soon after the grapes have set. as already mentioned in connection with the grape berry moth.

GRAPE LEAF-HOPPER.

Throughout the United States and Canada, wherever the grape is grown, this small leaf-hopper (*Typhlocyba comes* Say) will almost invariably be found in greater or less numbers infesting the lower surface of the leaf, where it feeds and breeds, increasing in numbers as the season progresses, until by late summer and fall the vines are often literally swarming with it. Throughout its extended range the insect may be quite destructive in some localities nearly every year, and is likely to become so elsewhere at any time. The grape leaf-hopper is an insidious pest, often not noticed by the vineyardist until late summer and fall, when the yellow and brown-blotched leaves, falling prematurely, attract attention, by which time the injury has been done. The insects in feeding extract large quantities of liquid food, sucking it out from the interior of the leaf by means of their tube-like mouth-parts. When they are abundant this constitutes a heavy drain on the vitality of the plant. The injury to and loss of leaves prevents the proper assimilation of food by the vines; the fruit may be materially reduced in quantity and will lack much in flavor and sugar content. Although the yearly loss to grape growers from the attack of this species is sufficient to place it among the first-class pests of the vine, but little effort ordinarily is made to control it, perhaps principally because no very practicable remedy has until recently been proposed. In the literature of the species there are many records of serious outbreaks of the pest here and there over the country, and recently the insect has attracted more than usual attention on account of serious injury in the Chautauqua and Erie grape belts, where it has been carefully studied by Professor Slingerland.[a]

Description and Life History.

The adult grape leaf-hopper is quite small, measuring not more than one-eighth of an inch in length. It is very agile, moving with almost equal facility in all directions, and flies out from the vines often in swarms upon slight disturbance. The general appearance of the insect is shown in figure 6, the back of the insect being marked with yellow or red, the exact pattern and color varying much among different individuals and according to season. There are numerous varieties of the insect based on these variations, several varieties often occurring together on the same vine, though more usually insects showing one type of color pattern will be found to predominate. The insect passes the winter in the adult condition in hibernation in trash in and near vineyards, in the edges of neighboring woods, in grass along gullies, in ditches, etc. Early in the spring the insects come from winter quarters and attack almost any succulent vegetation at hand. By the time the foliage of the grape appears they are out in large numbers and begin to infest the vineyards. These adult hoppers of the

[a] Bul. 215, Cornell Agrl. Exp. Station (1904).

hibernating generation feed and breed on the lower or earlier-appearing leaves, gradually disappearing as the season progresses, but not before some of their progeny have reached the adult condition. Some weeks are spent by the adults in the spring in feeding before egg-laying begins. Eggs are placed just beneath the epidermis in the lower leaf surface, usually singly but also in groups of from 6 to 9, the egg stage, according to Professor Slingerland, lasting from 9 to 14 days. Egg-laying probably continues for two months or more. When just hatched the young hopper is very small, whitish in color, with red eyes, later becoming striped with yellow. In the course of their growth these nymphs molt four times, the white skins being very numerous on the lower surfaces of badly infested leaves, as shown in figure 6, at *g*. The nymphs feed in the same manner as the parents, sucking juices from the leaves, at first on the lower surface of the older leaves where they were born, but later spreading more or less generally over the plant. They are very agile,

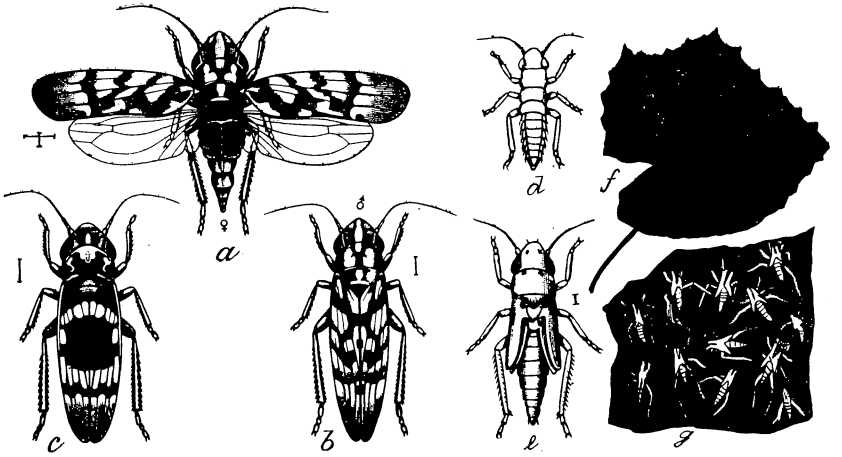

FIG. 6.—Grape leaf-hopper (*Typhlocyba comes*): *a*, Adult female; *b*, adult male; *c*, another form of the species, showing variation in markings; *d*, newly-hatched nymph; *e*, last stage nymph; *f*, appearance of injured leaf; *g*, cast pupa skins. *a-e*, Much enlarged; *g*, less enlarged; *f*, reduced. (From Marlatt.)

running in all directions, but do not leap or hop. In New York State Professor Slingerland found that from 30 to 35 days were required for their development in summer to the adult, and that there is but one full generation and a partial second brood of nymphs each year, the individuals of this partial second brood probably not maturing before frost. In warmer parts of the country two full generations or more are probable, since Gillette has shown this to be the case for Colorado and Townsend for New Mexico. By late summer the insects are often exceedingly abundant, and all stages are to be found on the leaves. The continued effect of their feeding is very apparent, the leaves being yellow and brown-blotched, the older ones most affected (figure 6, *f*). Feeding continues until the approach of cool weather, when the "hoppers" seek suitable hibernation quarters, as stated.

Remedial Measures.

The grape leaf-hopper has proved to be a difficult pest to combat successfully. Various practices have been proposed, such as the use of trap lanterns to burn at night, the raking and burning during winter of fallen leaves and trash in vineyards, the use of sticky shields or fans to catch the adults as they fly from the vine on being disturbed, and in California the use of insect nets for the same purpose.

Extensive field experiments were made by Professor Slingerland and his assistants in 1902 in Chautauqua vineyards against this pest, and fully recorded in Bulletin 215 already cited. He found that large numbers of the hibernated adults could be caught on sticky shields carried along each side of the row, the insects being frightened out by disturbing the vines. This work is done early in the season, before oviposition takes place to any extent. A light wooden frame is made, 7 or 8 feet long by 4 feet high. To the crosspiece at the bottom, which should be up from the ground about a foot, are fastened several stiff wires of the shape of a hayrake tooth. These are fastened so that the points curve inward and downward to the ground at base of plants when the shield is held in place beside the vines. The whole framework, including the wires, is covered with oilcloth which is coated with a sticky substance, made by using melted resin, 1 quart, and castor oil, 1 pint.

Early in the season the insects will be found mostly on the lower leaves and the frame need not be high. As the higher leaves are invaded the height of the frame must be increased. In controlling the insects in this way it is very important to catch the over-wintering adults before egg laying has begun, thus greatly reducing the number of progeny to appear later, and the operation of catching the insects must be repeated at frequent intervals.

Extensive tests with sprays were also made, and it was found practicable to destroy the young wingless hoppers or nymphs with a whale-oil soap solution, the soap being used at the rate of 1 pound to 10 gallons of water. The spraying must be done very thoroughly, covering the under surface of the leaves, as only those nymphs are killed which are actually hit with the spray. This work should be begun when it is observed that the young are becoming common. In the Chautauqua and Erie grape belts this will be early in July. There will be less foliage to treat at this time than if the work be deferred until somewhat later. Repeated applications may be necessary, especially if the work is not thoroughly done. It has been noted by Mr. Fred Johnson, of this Bureau, that whale-oil soap leaves a stain on the fruit at picking time, greatly lessening its market value for dessert purposes. It is likely that an 8 to 10 per cent kerosene emulsion could be used, which would obviate this difficulty, and would prove equally effective in killing the young hoppers.

Thorough cleaning up of fallen leaves and trash in vineyards during the winter will undoubtedly destroy many hibernating adults, and if this work be extended to adjacent areas where the insects are likely to find shelter, the reduction in their numbers will be materially greater. Where practicable the burning over of adjacent meadows, wood lots, and spaces along fences is very advisable. It has been observed that in vineyards in which clean culture is practiced, all grass and weeds being kept down throughout the season,

the "hoppers" are notably less abundant than where this practice is not followed. The absence of suitable hibernation quarters in the vineyard causes them, largely, to migrate elsewhere, and vineyards receiving such care are much less seriously infested the following spring and summer.

The grape leaf-hopper secures its food by sucking juices from the interior of the leaf, and arsenical poisons useful against the grape root-worm and the grape berry moth are quite useless against this pest.

GRAPE LEAF-FOLDER.

Observing grape growers have often noticed, especially during midsummer and later, grape leaves folded together, the interior (upper) surface of the leaf being more or less skeletonized, and within the fold a slender larva, which, upon being disturbed, is apt to wriggle out and fall or hang suspended by a thread. This insect, the grape leaf-folder (*Desmia funeralis* Hübner; see fig. 7), is widely distributed and a few are to be found in vineyards almost every year, while here and there throughout their range they may be so abundant as to do serious injury. There are two broods each year in the more northern States and three or possibly more in the South. The insect winters in the pupal stage in the folded and fallen leaves, the moths appearing in the spring shortly after the foliage puts out, and the eggs are placed in small patches here and there on the vine. Upon hatching; the young larvæ attack the foliage, folding the leaves as stated. Mr. Johnson has observed that larvæ of the first brood may attack bunches of grape blossoms and young fruit in a way similar to the grape berry moth. In 3 or 4 weeks the larvæ are full grown and transform to pupæ within the folded leaves, moths emerging some 8 or 10 days later. By midsummer and fall the insects may become quite abundant, and in badly infested vineyards the folded leaves are everywhere in evidence and are quite conspicuous from the color of the lower surface. In the fall the larvæ pupate in the folded leaves and pass the winter in these on the ground.

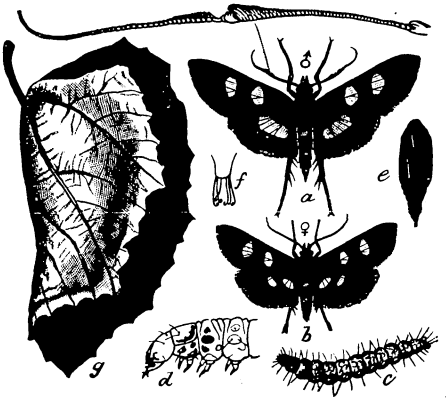

FIG. 7.—Grape leaf-folder (*Desmia funeralis*): *a*, Male moth and enlarged antenna of same; *b*, female moth; *c*, larva; *d*, head and thoracic segments of same, enlarged; *e*, pupa; *f*, tip of pupa, enlarged; *g*, grape leaf folded by larva. (From Marlatt.)

Treatment.

Where the insects are but moderately abundant it will be quite practicable to search out the folded leaves and crush between the hands the larvæ or pupæ within. The destruction of the first brood in this way would greatly reduce the number of the insects later in the season.

Vines sprayed with arsenicals for the root-worm and the berry moth will be well protected from the leaf-folder, for in this way the majority of the leaves will be sufficiently poisoned to insure the destruction of the larvæ and prevent the folding of the leaves. After a leaf has been folded the larva is practically safe from poisoning. As the winter is spent in the pupal stage in the leaves on the ground, many of the insects may be destroyed by collecting and burning the fallen leaves, as recommended in the case of the grape berry moth and the leaf-hopper.

GRAPEVINE FLEA-BEETLE.

Early in spring, as the buds of the grape begin to swell and burst, these may be scooped out or entirely consumed by a small blue or greenish beetle (*Haltica chalybea* Illiger), measuring about one-fifth of an inch in length, of robust shape, with thick thighs, and jumping

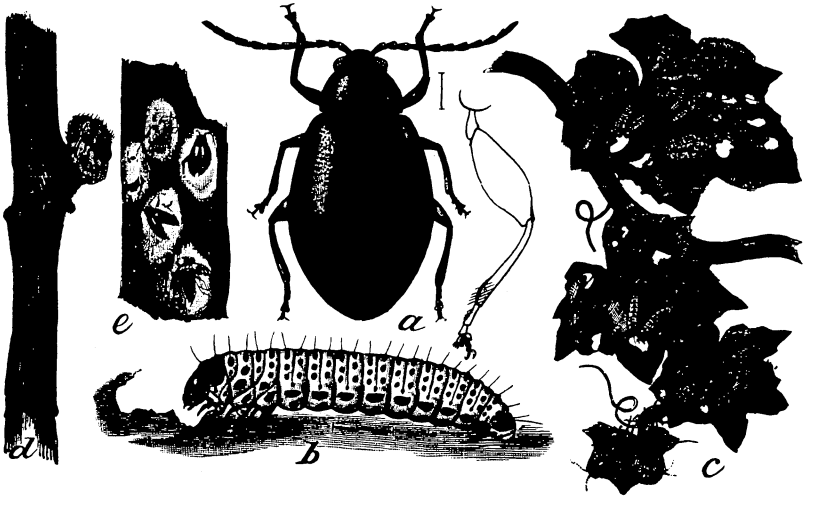

FIG. 8.—Grapevine flea-beetle (*Haltica chalybea*): *a*, Adult or beetle, with more enlarged leg at right; *b*, larva; *c*, larvæ and beetles on foliage; *d*, injury to buds; *e*, beetles killed by fungus. *a*, *b*, Much enlarged; *c*, *d*, *e*, about natural size. (From Marlatt.)

readily from the vines upon being disturbed (see fig. 8). When the beetles are abundant all of the buds on the vines may be quite destroyed, greatly retarding leafing out or even causing the death of the plant. Later the young foliage is eaten by the beetles, the females depositing their eggs more or less on the leaves, but largely, according to Slingerland,[a] in cracks in the bark at base of buds, between bud scales, or even in the holes which have been eaten into the buds. The resulting larvæ feed on the leaves of the grape, mostly on the upper surface, and are thus readily destroyed with sprays. In 3 or 4 weeks the grubs have attained full growth; then, dropping to the ground, they make an earthen cell an inch or so below the surface, and transform to pupæ, from which the adult beetles will emerge in the course of 1 or 2 weeks. The new brood of beetles feeds upon the grape and other plants, going into hibernation in the fall and appearing the next

[a] Bul. 157, Cornell Univ. Agrl. Exp. Station (1898).

spring to attack the buds of the grape, as stated. In the Northern States Slingerland's studies have shown but one generation of the insect each year. In the South two or more generations annually are supposed to occur, but definite evidence on this point is wanting.

The flea-beetle is native to North America, and occurs very generally throughout the eastern half of the United States, its western limits being Minnesota, eastern Nebraska, Kansas, and Texas. Its natural food is undoubtedly the wild grape, though numerous other plants are fed upon, as plum, apple, pear, quince, blue or water beech (Carpinus), elm, etc.

Treatment.

In vineyards which are regularly sprayed with arsenicals and Bordeaux mixture the flea-beetle will be effectively kept in check. The first application for the berry moth before the blossoms open, together with the application made after the blossoms fall, will destroy the larvæ, since these feed almost exclusively on the upper surface of the leaves. The insects thrive best in neglected vineyards, and may become quite abundant and destructive locally. Where it is desired to treat for this insect only, the vines should be thoroughly sprayed with an arsenical just as the buds are beginning to swell, or somewhat earlier. A close lookout must be kept for the first signs of the beetles, and the poison must be applied immediately. The delay of a day or so may mean the loss of the buds, and hence of the fruit crop. In the small home vineyard it will be practicable to search out the beetles and remove them by hand, doing the work in the morning when they are less agile. As stated, the destruction of the larvæ when feeding on the foliage later will be very easily accomplished by spraying with arsenicals.

It will also be quite practicable, as stated by Doctor Howard, to jar the beetles from the vines on canvas frames placed beneath, which should be kept saturated with kerosene.

ROSE-CHAFER.

About the time of blooming of the grape in the spring the rose-chafer (*Macrodactylus subspinosus* Fabricius) may suddenly put in an appearance, often in enormous numbers, the long, spiny-legged, awkward, brownish beetles literally covering the plants, feeding at first upon the blossoms, but later attacking the young fruit and foliage, the leaves being eaten bare, except the larger veins (see fig. 9). This insect is a very general feeder; it attacks practically all fruits—e. g., apples, plums, cherries, peaches, etc.—as well as various vegetables, grains, and grasses. Many ornamental plants, such as Spiræa, Deutzia, and roses, are attacked, and its injuries to the last-mentioned have led to the use of the common name of "rose-chafer" or "rose-bug," though it is perhaps now most commonly complained of from its injuries to grapes and other fruits. When abundant, the beetles may do serious injury in vineyards, quite destroying the blossom clusters or the newly set fruit. Berries not actually devoured are often so marked by the beetles that they become misshapen and crack as they grow, the seeds often protruding. After 3 or 4 weeks of feeding the beetles may disappear almost as suddenly as they came.

The rose-chafer is rather widely distributed, occurring from Canada south to Virginia and Tennessee and west to Colorado. It is recorded also from Oklahoma and Texas, though west of the Mississippi it is apparently not very injurious. In the New England and Central States it is more abundant, and is most troublesome perhaps in New York, Pennsylvania, New Jersey, Delaware, Maryland, Virginia, and Ohio, large outbreaks in ruinous numbers occurring more or less locally where the soil is light and sandy.

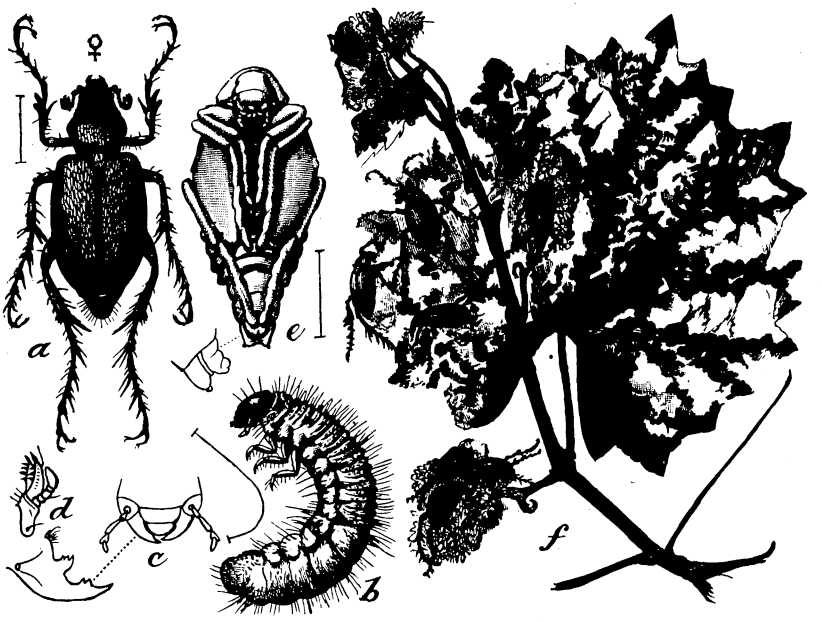

FIG. 9.—Rose-chafer (*Macrodactylus subspinosus*): *a*, Adult or beetle; *b*, larva; *c*, *d*, mouth parts of same; *e*, pupa; *f*, injury to leaves and blossoms of grape, with beetles at work. *a*, *b*, *e*, Much enlarged; *c*, *d*, more enlarged; *f*, somewhat reduced. (From Marlatt.)

Breeding Grounds.

The insect lives in the larval stage underground, feeding on the roots of various plants, especially on the roots of grasses. Doctor J. B. Smith found larvæ in abundance in a vineyard in New Jersey and in a blackberry patch, feeding apparently on the roots of grasses and weeds which grew sparsely between the rows, and larvæ were still more numerous under the sod bordering the vineyard. In an adjacent meadow, where the soil was heavier and less sandy, no larvæ could be found. In general, the insects breed principally in light sandy soils, especially in meadow lands, but also in other places where there is more or less of growth of grass and weeds, and, to a less extent, in cultivated ground. Wet, clayey, or compact soils do not furnish desired conditions for the insects, and from the fact that they are largely confined to the lighter soils it becomes practicable to reduce them greatly by planting these to annual crops which receive thorough cultivation.

Life History.

The beetles deposit their eggs singly, burrowing beneath the soil, laying, according to Doctor Smith,[a] from 12 to 20 eggs. The resulting larvæ feed upon the roots of various grasses and possibly weeds and other vegetation. They are mostly full grown by fall, and burrow below the frost line, where the winter is spent. With the coming of spring the grubs ascend toward the surface and enter the pupa stage, from which in from 10 to 30 days, varying with the temperature, the beetles develop and attack the grape and other plants, as stated. There is thus but one generation each year, the principal injury of the insect being done during the 3 or 4 weeks of its life as a beetle.

Treatment.

The rose-chafer is an exceedingly difficult insect to combat successfully. When the insect occurs only in moderate numbers, arsenicals will be reasonably satisfactory; but when it occurs in swarms, the plants are reinfested as fast as the insects are killed. It is possible, however, that a heavy application of arsenate of lead, say 5 to 6 pounds to 50 gallons of water or Bordeaux mixture, will largely protect the vines, and this plan should be tested by vineyardists confronted with this pest. Very thorough applications should be made upon first signs of the insects and repeated as necessary. Many different substances have been applied to vines to render them obnoxious to the beetles, but none of these has proved to have any special value. Perhaps the method most generally relied upon is picking or jarring the beetles from the vines. In the latter work an umbrella-shaped frame with a canvas or oil cloth covering, with a can of kerosene at the bottom, is frequently used, being held under the vines, which at the moment are sufficiently shaken to cause the beetles to fall. Jarring or hand-picking must be done every morning, or, better, twice a day, during periods of severe infestation.

The numbers of this insect may be considerably lessened by restricting its breeding grounds. In vineyards on sandy or light soil especial care should be taken to keep the rows and surroundings free from weeds and grass, upon the roots of which the larvæ feed. Sandy meadow lands in the vicinity of vineyards should be broken up and cultivated to annual crops, and in this work the cooperation of vineyardists throughout a neighborhood is especially important.

Bagging grapes as soon as the fruit has set is often practiced, and affords protection not only against further injury from the rose-chafer, but also from the grape berry moth, the grape curculio, and fungous diseases of the fruit.

INSECTICIDES.[b]

ARSENICALS.

Arsenicals, applied in the form of a spray, are effective against the grape root-worm, the grape berry moth, the grape curculio, the grape leaf-folder, and other insects which devour the foliage

[a] Bul. 82, N. J. Agrl. Exp. Station (1891).

[b] For a more extended account of insecticides, see Farmers' Bulletin 127, U. S. Dept. of Agriculture, by C. L. Marlatt.

and fruit. The arsenical is best used as an ingredient added to the Bordeaux mixture, which is the standard remedy for the control of fungous diseases. When an arsenical is used simply in water the vineyardist should always add, to each 50 gallons of the liquid, the milk of lime made from slaking 2 to 3 pounds of good stone lime.

Paris green.—This is used at the rate of 1 pound to each 100 or 150 gallons of liquid, whether water and milk of lime or the Bordeaux mixture. Paris green should be worked into a paste with water before being added to the liquid in the spray tank, to prevent its adhering in small lumps. When used with Bordeaux mixture, the latter will probably serve to hold it well on the vines, giving results perhaps equal to those produced by arsenate of lead.

Scheele's green.—This arsenical is similar to Paris green, being the simple arsenite of copper containing no acetic acid, and hence considerably cheaper. It is a much finer powder than Paris green and remains in suspension longer. It is used in the same way and at the same strength recommended for the former poison.

Arsenate of lead.—There are now numerous brands of arsenate of lead on the market, and vineyardists should be careful to buy an efficient and safe kind. Some preparations sold as arsenate of lead contain an amount of free arsenic dangerous to foliage, and an unnecessary amount of water may also be present, thus lowering the quantity of poison when used at a given strength. A proper arsenate of lead should contain no free arsenic and should have as much as 50 per cent actual arsenate of lead. Arsenate of lead is used at the rate of 3 to 6 pounds to each 50 gallons of liquid, and, as it comes in the form of a putty-like paste, must be worked free in a little water in a bucket or other suitable vessel before it is added to the spray tank. It may be used much stronger than any other arsenical and it adheres well to the foliage. For these reasons it is preferred by many vineyardists.

Arsenite of lime.—This is much the cheapest of the arsenical poisons. On apple it is stated to be very satisfactory, and it should be equally so on grape. It seems not yet to have been used to any extent on grape, and should be tried first in a small way. It may be prepared at home according to the following formula:

White arsenic	pounds..	1
Sal soda crystals	do....	4
Water	gallon..	1

All of the ingredients are boiled together for a few minutes or until dissolved, and any water lost by evaporation should be restored. This constitutes a stock solution, 1 pint being used with each 40 or 50 gallons of Bordeaux mixture. When it is used in water the vineyardist must add the milk of lime made from slaking 2 to 3 pounds of good stone lime, which is necessary to produce the arsenite of lime.

CONTACT REMEDIES.

For insects which secure their food by sucking the juices from the plant, such as the grape leaf-hopper and aphides, contact insecticides must be used. Two such insecticides are whale-oil soap solution and kerosene emulsion. These preparations are not ordinarily used in Bordeaux mixture. They are sprayed on the vines in the usual way.

Whale-oil soap.—For vines in foliage, whale-oil soap is used at the rate of 1 pound to 8 or 10 gallons of water. There are several grades of this article on the market, but a potash whale-oil soap is best, especially one that does not contain more than 30 per cent of water.

Kerosene emulsion.—This doubtless will be equally satisfactory as a spray against the grape leaf-hopper, and may be prepared as follows:

Whale-oil or other soap	pounds..	2½
Kerosene (150 flash test)	gallons..	5
Water to make	do....	50

The soap is dissolved in 6 to 8 gallons of hot water, and the kerosene is at once added. The whole is then thoroughly emulsified by the use of a hand pump, pumping the liquid back upon itself for 8 or 10 minutes or until a creamy-white emulsion results. This, when diluted with the required amount of water, will contain 10 per cent of kerosene, which strength should be effective in destroying young hoppers without injuring the foliage or the fruit. If a smaller quantity of emulsion than 50 gallons is desired, it may be made, simply observing the proportions given.

FUNGOUS DISEASES.

The fungous parasites of the American varieties of grape are indigenous, and came originally from the native wild vines. With the gradual extension and development of the grape-growing industry there has also been an increase in the distribution and destructiveness of these fungous diseases. The conditions which necessarily obtain in commercial grape culture have disturbed the equilibrium which had become established between the vine and its parasites in their wild state, and have facilitated the production and distribution of the diseases. In the selection and breeding of the grape attention has been devoted chiefly to the improvement of the fruit, and this has apparently resulted in a decrease of the natural powers of resistance to disease originally possessed by the wild vines.

In certain sections of the country where grape growing was once a profitable industry it has largely been abandoned, chiefly on account of the great loss caused by disease. The amount of loss from fungous diseases of the grape in the eastern half of the United States during the past season (1906) is estimated at from 15 to 20 per cent of the entire crop. In some localities it reached 40 to 50 per cent, and in some particular vineyards where there was promise of a crop of 4 or 5 tons per acre the loss was total, while in one favored region the loss was not over 5 per cent.

Injury due to fungi depends largely upon weather conditions. The conditions most favorable for the development of the majority of the fungous diseases are excessive moisture and heat. The general physiological condition of the vines is also important. Vines which are kept thrifty and vigorous by proper care and cultivation are not

likely to suffer so severely from most diseases as those which are neglected.

The principal fungous diseases in the order of their importance are black-rot, downy mildew, powdery mildew, anthracnose, and ripe-rot. There are also other diseases, which will be referred to later, but they are either not of sufficient importance to deserve much attention here or else their treatment is not yet satisfactorily determined.

BLACK-ROT.

Black-rot is the most generally distributed and destructive fungous disease of the grape in the region east of the Rocky Mountains. It is caused by a parasitic fungus known as *Guignardia bidwellii* (Ell.) V. & R. It gains entrance to the plant by means of minute germs called spores. These are borne in small black spore cases, and can

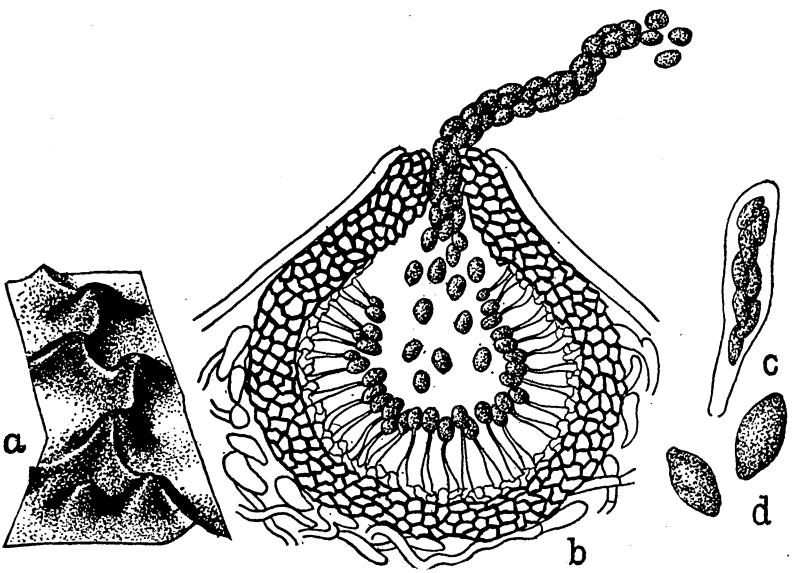

FIG. 10.—The black-rot fungus (*Guignardia bidwellii*): *a*, A portion of an affected grape, showing the pustules in which the spores are produced (slightly magnified); *b* a section of one of these pustules very highly magnified, showing the manner in which the summer spores are produced and discharged; *c*, a sac containing winter spores; *d*, single winter spores very highly magnified.

not be seen with the naked eye. They are distributed chiefly by the wind and rain. Two or more forms of spores are produced, as shown in the accompanying illustration (fig. 10, *b*). When these spores come in contact with the young and tender parts of the vine, under favorable conditions, they germinate and produce a slender tube, which penetrates the tissue and may destroy it.

This disease attacks the leaves and shoots, as well as the fruit. It usually makes its first appearance on the leaves and young shoots, producing reddish-brown dead spots. The fruit may be attacked when young, but usually the disease does not attract attention until the berries are half grown or more. Brown or blackish spots first

appear; these spread and soon affect the whole berry, which becomes black and shriveled, as shown in the accompanying illustration (fig. 11). These diseased berries remain attached to the vine, and their surfaces become covered with minute black pustules, which contain the summer spores of the fungus. During the winter and spring another form, called the winter, or resting spore, is produced upon these old, shriveled berries (fig. 10, *c*, *d*). These spores help to carry the disease over from one season to another. This fact would indicate the desirability of destroying, by burning, all diseased fruit, as well as leaves and prunings, as early in the spring as possible.

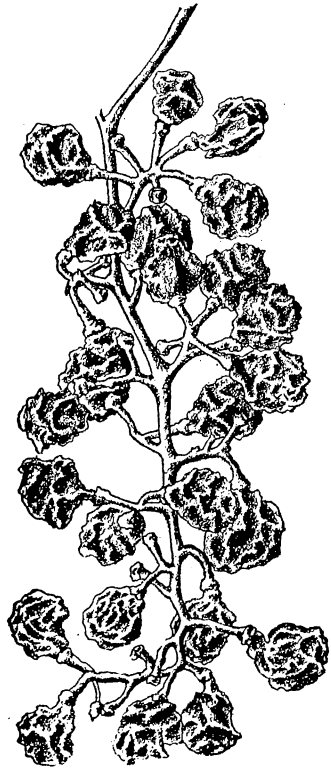

FIG. 11.—A bunch of grapes destroyed by black-rot.

Treatment.

This disease can be effectually controlled by thorough spraying with Bordeaux mixture. Five or six applications are usually necessary during the season, the first being made just before the buds open. For the last one or two applications, some fungicide which does not stain the fruit should be used. Burgundy mixture is recommended for this purpose. Full directions regarding the preparation of the fungicides and the times of application will be found later.

Covering the bunches of grapes with paper bags soon after the blossoms fall is a means of preventing black-rot and most other fungous parasites. It is usually regarded as too laborious and expensive for large vineyards, but may be profitably practiced where only a small number of vines are grown.

DOWNY MILDEW.

Downy mildew (*Plasmopara viticola* (B. & C.) Berl. & De Toni) in certain seasons and in northern localities sometimes causes more loss than black-rot and is a close rival for first place among the fungous enemies of the grape. It attacks all the tender growing parts of the vine. Usually it is at first most noticeable on the foliage, producing greenish yellow, irregular spots upon the upper surface, which become reddish brown. At the same time there appears on the under surface of the leaf a thin, loose, white, downy growth, suggestive of hoar frost (fig. 12). This growth consists of the fertile fungous filaments bearing the summer spores (fig. 13, *a*, *b*), which under favorable conditions are distributed by the wind and water to the berries and other parts, where they germinate, penetrate the tissues, and continue their destructive work. The young shoots are also frequently attacked and killed.

The fruit, if attacked when young or only partly grown, shows first a brownish spot, and later becomes covered with the gray, downy growth of the fungus. This form of the disease is sometimes called "gray-rot" by vineyardists (fig. 14). When the berries escape the disease until they are half grown or more it appears as a brownish or brownish purple spot which spreads and soon involves the whole berry. The affected fruit becomes soft and wrinkled and falls to the ground when disturbed. This stage of the disease is sometimes called "brown-rot."

FIG. 12.—A grape leaf attacked by the downy mildew (*Plasmopara viticola*), showing the appearance of the leaf above and below.

Besides the summer spores mentioned, there is also produced within the diseased tissues another form of reproductive body, sometimes called a winter, or resting, spore (fig. 13, *c*). These spores are produced in much smaller numbers than the summer spores and are provided with a rather thick, dark-colored outer covering apparently intended for their protection during the winter.

This disease, like the black-rot and many others, develops most rapidly and does most injury during hot, wet weather.

Treatment.

It is desirable to destroy as many as possible of the diseased leaves, shoots, and berries, which may contain the winter spores. Thorough spraying, as recommended for the black-rot, will effectually control this disease.

POWDERY MILDEW.

The powdery mildew (*Uncinula necator* (Schw.) Burr.) rarely causes great loss to American varieties of grapes. It is most severe on the European, or vinifera, grapes. This mildew belongs to a group of fungi quite different from the downy mildew.

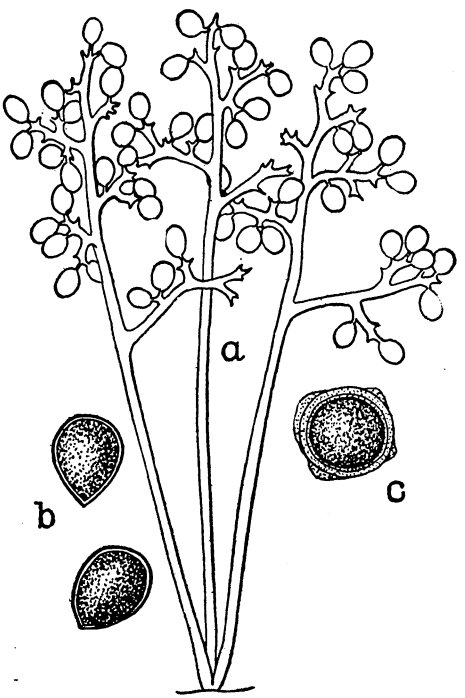

FIG. 13.—The fungus causing downy mildew: *a*, Fertile filaments of the downy mildew fungus, showing the manner in which the summer spores are borne; *b*, two summer spores; *c*, a winter, or resting, spore. (All highly magnified.)

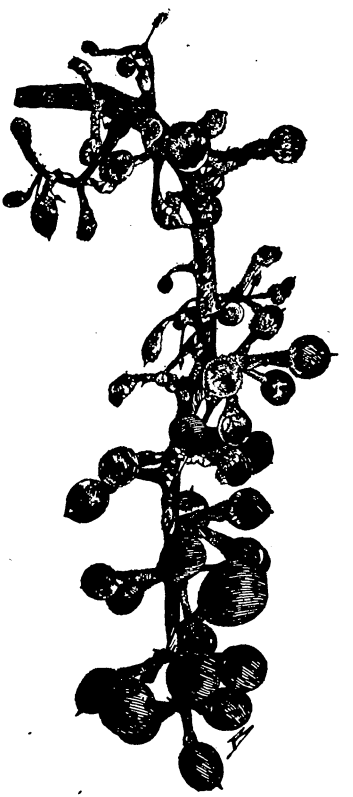

FIG. 14.—A bunch of young grapes partially destroyed by "gray-rot." This is a form of the downy mildew affecting the very young fruit.

It differs from all other parasites which attack the grape in its superficial habit of growth. The filaments of the fungus do not invade the tissues of the plant to destroy them. The parasite obtains its nutriment by means of sucker-like organs which penetrate the cell walls of the surface layer of tissue only. The fine, white filaments of the fungus, which constitute the vegetative portion of the parasite,

spread over the surface of the leaves, shoots, and fruit, and send up short, irregular branches upon which immense numbers of summer spores are produced in short chains (fig. 15, *a*). These are most noticeable upon the upper surface of the leaf, giving it a fine gray, powdery, or mealy appearance. Finally the affected part of the leaf becomes light brown, and if the disease be severe the leaves fall. The fungus produces a similar appearance upon the young shoots. Berries which are attacked take on a gray, scurfy appearance, become specked with brown, and fail to develop further. Affected grapes when nearly half grown sometimes burst open on one side, exposing the seeds. The fruit does not become softened and shrunken as when attacked by the downy mildew.

Besides the summer spores, winter, or resting, spores are also produced in the latter part of the season. These are borne in sacs which

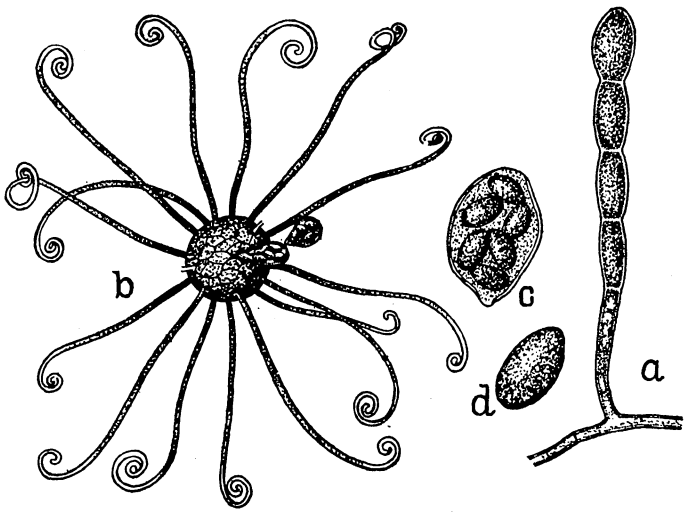

FIG. 15.—The fungus causing powdery mildew (*Uncinula necator*): *a*, A fertile filament of the fungus bearing a chain of summer spores; *b*, a spore case, in which the winter or resting spores are produced; *c*, a single sac containing winter spores; *d*, a single winter spore. (All highly magnified.)

are inclosed in minute black, globose fruiting bodies furnished with slender appendages curled at their tips (fig. 15, *b*, *c*, *d*). These black spore cases are so small that they can scarcely be seen with the naked eye, but by the aid of a hand lens they can be easily observed. The powdery mildew is usually more prevalent during dry, hot seasons than in wet ones. It differs in this respect from most of the other grape diseases. In California this is the principal fungous disease of the grape.

Treatment.

Bordeaux mixture, as recommended for the black-rot, will prevent this disease. Where this trouble alone is to be combated it may be successfully done by dusting with flowers of sulphur. East of the Rocky Mountains, however, it should be treated with Bordeaux mixture, as it is rarely likely to occur alone.

ANTHRACNOSE.

Anthracnose (*Sphaceloma ampelinum* De By.) has also been called "bird's-eye rot," on account of the peculiar spots it produces upon affected grapes. Like most of the other diseases of the grape, it attacks the leaves and shoots as well as the fruit. On the leaves it at first appears as minute, irregular, dark brown, slightly sunken spots, having a darker margin. These spots usually become lighter colored when old, and frequently crack or fall out, leaving irregular holes in the leaves. This disease presents much the same appearance on the shoots as on the leaves, though the spots are frequently larger and more sunken (fig. 16). They also tend to run together and form irregular patches.

FIG. 16.—Grape shoot, showing spots produced by anthracnose (*Sphaceloma ampelinum*).

The disease is most characteristic and conspicuous upon the fruit. The spots are usually brown at first and surrounded by a narrow, dark purplish margin; they increase in size and gradually become grayish white and somewhat sunken. Frequently two or more spots unite and cover a considerable part of the berry (fig. 17). The affected tissues do not become softened, as in the case of the downy mildew, but the fruit becomes hard and more or less wrinkled. If only a small part of the berry is affected it may continue to grow, causing the diseased area to rupture and the seeds to become exposed. The bursting of the berries and the exposure of the seeds may, however, be produced by other causes, such as the powdery mildew and certain physiological disturbances.

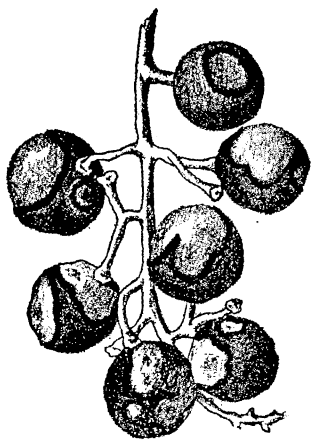

FIG. 17.—Portion of a bunch of grapes, showing the effect of anthracnose.

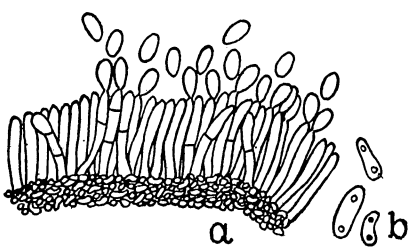

FIG. 18.—Section of an anthracnose spot, highly magnified: *a*, Showing the way in which the spores are borne; *b*, three of these spores more highly magnified.

On the diseased areas the minute spores or germs of the fungus are frequently produced in immense numbers. The way in which these spores are borne is shown in figure 18. No special winter form of spore is known to be produced by this fungus. The fine, thread-like filaments which constitute the vegetative part of the parasite live during the winter in the tissues of the vines and are ready for active growth in the spring.

The anthracnose is quite widely distributed in this country, but

fortunately has not caused any great general loss. It should be carefully watched, however, as, when once well established under favorable conditions, its eradication is very difficult.

Certain varieties, such as Diamond, Brighton, Agawam, and Salem, are especially susceptible to this disease.

Treatment.

All diseased shoots should be cut and burned, as it is believed that it is through these that the disease is chiefly transmitted each season. Spraying with Bordeaux mixture, as recommended for black-rot, when accompanied by thorough cutting and burning of diseased parts, is likely to prove sufficient, except where the disease is unusually severe, in which case the treatment which has been adopted and found very successful in Europe may be followed. This consists of the application of the following mixture:

Sulphate of iron (copperas)	....pounds..	110
Sulphuric acid, commercial	.....quart..	1
Hot water	.....gallons..	26

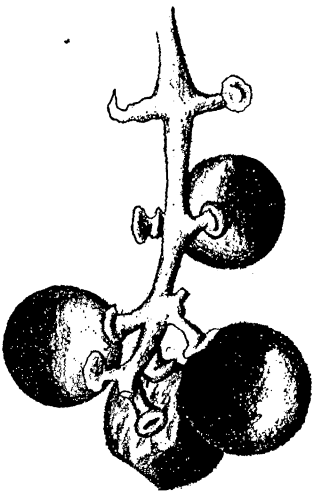

FIG. 19.—Grapes attacked by the ripe-rot (*Glomerella rufomaculans*).

First pour the acid upon the copperas and then add the water. This mixture should be prepared and handled with great care, as it is exceedingly caustic and will injure the skin, clothing, and almost everything with which it comes in contact. On this account it can not be applied with a common spray pump. A swab, made by attaching a bundle of rags to a stick, may be used in applying the mixture. All portions of the vines should be thoroughly covered with this preparation just before the buds begin to swell in the spring.

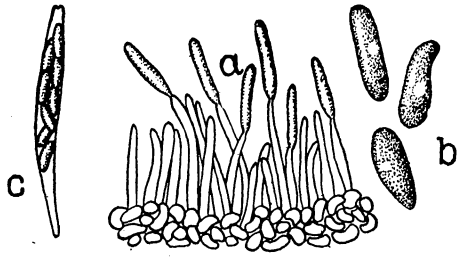

FIG. 20.—The fungus producing ripe-rot (*Glomerella rufomaculans*): *a*, Summer spores, showing the manner in which they are borne; *b*, the same spores, more highly magnified; *c*, a sac containing winter spores.

RIPE-ROT.

Ripe-rot (*Glomerella rufomaculans* (Berk.) Spauld. & von Schrenk) has also been called bitter-rot. The name bitter-rot is, however, applied to another fungous disease of the grape, caused by *Melanconium fuligineum*. As the present name indicates, the disease usually appears on the fruit when the latter is nearly mature, and under favorable conditions continues its development and destruction after the grapes are picked. It also attacks the leaves and stems, but is most noticeable and injurious on the fruit. The first indication of the disease is the appearance of reddish-brown discolored spots (fig. 19),

which spread and finally extend over the whole fruit. The surface then becomes dotted with dark, slightly elevated pustules, in which the spores are borne (fig. 20, *a*, *b*.). At this stage of development this disease is not easily distinguished from the early stages of black-rot and bitter-rot. The berries do not shrivel up, however, as in the case of the black-rot, and usually are easily detached from the bunch. The spores mentioned are produced in large numbers and serve to spread the disease.

The fungus causing this disease is closely related to that which produces the bitter-rot of the apple, and by some is regarded as the same; but no entirely conclusive cross-infection experiments have yet been reported. The Department of Agriculture has demonstrated by means of pure cultures of this fungus that there is another stage, producing spores very similar in appearance to those just mentioned, but borne in sacs which are inclosed in spore cases similar to those of the black-rot fungus (fig. 20, *c*). This spore form is of very infrequent or doubtful occurrence in vineyards, and is probably not an important factor in the distribution of the disease.

It is difficult to determine how much injury is done by this disease on account of the liability of confusing it with other fungous troubles. It is quite generally distributed, and may cause more loss than is usually attributed to it.

Treatment.

Spraying as recommended for black-rot will largely prevent this disease. The later applications are especially important and should be very thorough.

LESS IMPORTANT DISEASES.

Bitter-Rot.

The bitter-rot of the grape is caused by a fungus known as *Melanconium fuligineum* (Scrib. & Viala) Cav. Fruit attacked by this disease presents an appearance quite similar to that produced by the ripe-rot. Bitter-rot is no doubt sometimes confused with other diseases. It is mostly restricted to the Southern States, and is not generally regarded as serious.

Treatment.—Spraying as for black-rot will probably prevent this disease.

White-Rot.

The effect of the disease known as white-rot (*Coniothyrium diplodiella* (Speg.) Sacc.) upon the fruit of the grape is somewhat similar to that of the brown-rot form of the downy mildew. It occurs in Missouri and the Southwest and has been reported as rather serious in some parts of Ohio.

Treatment.—There is nothing in the nature of this disease, so far as known, to indicate that it can not be satisfactorily controlled by the treatment recommended for black-rot. Sufficient knowledge of this subject to justify a positive statement in regard to treatment is not at present available.

Crown-Gall.

Crown-gall is a disease of somewhat uncertain origin, characterized by the formation of rough outgrowths, or excrescences, on the vines, usually near the surface of the soil. Certain forms at least are known to be contagious.

Treatment.—All plants bearing galls should be burned, and great care should be exercised to avoid planting diseased stock. Fungicides are apparently useless in combating this disease.

Root-Rot.

The roots of the grape are known to be attacked by several different fungi, especially when the root system has become weakened or injured by other causes. Two forms of root-rot are of sufficient importance to be mentioned here.

Vibrissea hypogæa.—The fungus known as *Vibrissea hypogæa* Ch. Richon & Le Monnier is usually associated with insect injury, caused either by Phylloxera or by the grape root-worm. It has been found in New York, Pennsylvania, and Missouri, and appears to hasten the death of plants, especially those on which the root-worm has been at work.

Treatment.—This root-rot can be prevented only by the destruction of the insects which injure the root system and thus give the fungus opportunity to gain a foothold.

Ozonium.—There is a root-rot of a more serious nature prevalent in and chiefly restricted to Texas and New Mexico. This is caused by a fungus known as Ozonium, which also attacks the roots of cotton and a great variety of other plants. It is most destructive in the black waxy, clay soils, which are very poorly aerated. Plants attacked die suddenly, the leaves and fruit withering up in a day or two and remaining on the vines.

Treatment.—No remedy is known for this root-rot of the grape. Soil upon which other plants have died with the same disease should be carefully avoided in planting vines.

Shelling.

The shelling or dropping of grapes from the bunches before maturity may be due to various causes. In some localities in New York and Pennsylvania this trouble is rather serious. The cases which the Department has had an opportunity to study have been found to be due mostly to an imperfectly known fungous disease, which appears to be induced chiefly by improper pruning and training. Allowing the vines to produce too heavy crops is also likely to increase this trouble. The subject is at present under investigation, and it is hoped to treat it separately in a later publication.

FUNGICIDES.

BORDEAUX MIXTURE.

Bordeaux mixture is the most efficient fungicide for general use at present known.

The 5-5-50 formula.—For ordinary use in combating grape diseases the following formula has given excellent results:

Copper sulphate (bluestone or blue vitriol)	pounds..	5
Fresh stone lime	do.....	5
Water	gallons..	50

At least 100 gallons of the mixture are generally prepared at one time. This amount can be made by using twice the quantity of each material directed to be used for 50 gallons, and for 150 gallons three times the quantity must of course be used.

The 4-4-50 formula.—A somewhat weaker mixture, prepared according to this formula, has been successfully used in some cases and may perhaps prove generally satisfactory if properly made and thoroughly applied:

Copper sulphate	pounds..	4
Stone lime	do.....	4
Water	gallons..	50

The 6-3-50 formula.—Bordeaux mixture for use before the buds open in the spring should be prepared according to this formula:

Copper sulphate	pounds..	6
Stone lime	do.....	3
Water	gallons..	50

For applications to dormant vines a simple solution of copper sulphate is often used, consisting of 4 pounds of copper sulphate to 100 gallons of water. The strong Bordeaux mixture is more efficient, however, as it adheres better to the vines and is effective for a longer period.

PREPARATION OF BORDEAUX MIXTURE.

Failure to secure satisfactory results from the use of Bordeaux mixture is frequently due to lack of proper care and thoroughness in its preparation, or to the use of poor material. All ready-made preparations of Bordeaux mixture in the form of a paste or a dust should be avoided, as the chemical constituents do not properly combine in these conditions. A definite chemical compound is desired, and this can only be produced in proper form and condition by carefully following the directions given below.

Stock Solutions.

In order to carry on the work with the greatest convenience and economy, a considerable quantity of copper sulphate and of lime should be ready for immediate use. The copper and the lime may be prepared and kept most conveniently in the following manner:

Copper sulphate solution.—Take 100 pounds of copper sulphate (bluestone), place it in a gunny sack, and suspend it in a 50-gallon

barrel of water. Kerosene or whisky barrels will be found very convenient. The copper sulphate will all dissolve in from 12 to 18 hours if suspended in a loosely woven sack, but if it is thrown loose in the bottom of the barrel it will take several days and considerable stirring to dissolve it. This makes a solution containing 2 pounds of copper sulphate to each gallon of water. This may be kept as long as desired without deterioration, if covered so as to prevent evaporation.

Lime solution.—The various kinds of ground and prepared lime can not always be relied upon; stone lime is therefore to be preferred, and is more likely to give uniformly satisfactory results. Slake 100 pounds of stone lime in a 50-gallon barrel, adding the lime in small quantities with plenty of water and mixing thoroughly. When the lime is all slaked fill the remainder of the barrel with water. You will now have a stock preparation of lime which when thoroughly mixed will be thin enough to dip and pour readily. Each gallon of this preparation will contain 2 pounds of the stone lime. This may be kept under cover and used as needed. Where large quantities of material are being used it is desirable to have two or more barrels each of stock lime and bluestone instead of one, so that the bluestone in one barrel may be dissolving while that in the other is being used.

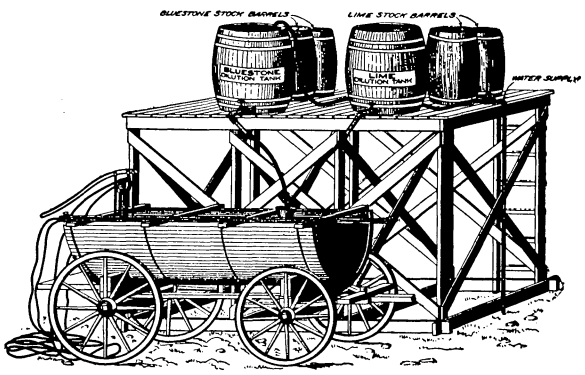

FIG. 21.—Elevated platform for making Bordeaux mixture. The water supply is merely indicated. In the absence of a water supply in pipes a water tank may be used. The materials flow by gravity directly into the spraying tank, which thus serves as the mixing tank.

Mixing Copper Sulphate Solution and Lime Solution.

To prepare a 100-gallon spray tank of Bordeaux mixture, take two 50-gallon barrels and fill them nearly full of water; to one barrel add 5 gallons of the bluestone stock solution, which will be the equivalent of 10 pounds of bluestone. To the other barrel add 5 gallons from the barrel of the stock lime preparation, which will be equal to 10 pounds of stone lime. Mix the lime thoroughly and allow the contents of the two barrels to run together into a trough, or through hose attached at the bottom of the barrels into the tank of the sprayer, as shown in the illustration (fig. 21).

If an insecticide is to be used, it may now be added to the mixture.

After the mixture is prepared it should be used very soon, and not be allowed in any case to stand more than a few hours before using.

The quantities mentioned in this account of the preparation of Bordeaux mixture will give 100 gallons of the 5–5–50 formula. For the other formulas, the manner of preparation is precisely the same, and the necessary changes in quantities of bluestone and lime are easily calculated.

Straining.

In order to avoid clogging the spray nozzles the mixture must be thoroughly strained before it goes into the sprayer. A strainer of brass wire cloth, 20 or 22 meshes to the inch, should be used for this purpose. A very convenient and satisfactory strainer is shown in the accompanying illustration (fig. 22). It consists of (1) a tight outer box about 1 foot square, with a heavy bottom, into which a piece of 1½ to 2 inch gas pipe is fitted as an outlet, and (2) an inner box, smaller and lighter, which will drop easily into the outer one. The wire cloth, securely fastened, forms the bottom of the inner box, and is sloped at an angle of about 30 to 35 degrees. The slanting of the sieve prevents clogging, and the removability of the inner box greatly facilitates cleaning. A narrow strip should be nailed about the outside of the inner box at the top, so as to prevent its dropping too far down; this will facilitate its removal.

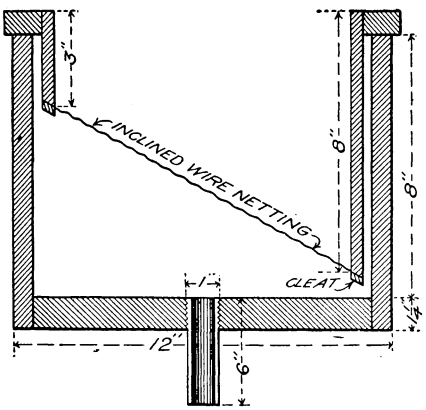

FIG. 22.—Cross section of strainer for Bordeaux mixture. The inner frame with inclined wire strainer fits loosely into the outer box.

Elevated Platform.

A platform similar to the one shown in the accompanying illustration (fig. 21) will be found very convenient in handling the stock solutions and the mixture. This should be located near a good water supply. A tank elevated above the mixing platform and filled by a windmill pump will be found very convenient, or the platform may be located beside a stream or spring and the water be raised by means of a force pump.

NONSTAINING PREPARATIONS.

Bordeaux mixture, when used late in the season, is apt to stain the fruit more or less and interfere with its sale. It is therefore best to use for the final applications some other fungicide which is not open to this objection. The amount of the mixture which may adhere to the grapes at the time they are picked is not sufficient to injure the consumer under normal or average conditions. Consumers, however, object to stained fruit, and this fact must be taken into account.

The following preparation, though not quite so efficient a fungicide as Bordeaux mixture, does not stain the fruit, and should, therefore, be used for the last two applications.

Burgundy mixture (copper carbonate mixture).

Copper sulphate	pounds..	2
Sodium carbonate (sal soda)	do....	3
Water	gallons..	100

Dissolve and dilute each of the two chemicals to 50 gallons and allow them to run together into the spray tank in the same manner as in making Bordeaux mixture.

Insect poisons should not be added to this mixture.

Ammoniacal copper carbonate has been recommended in previous Farmers' Bulletins as a nonstaining application. Copper acetate has also been suggested for the same purpose. According to our present knowledge Burgundy mixture is about as safe and efficient as either of these and costs less than half as much.

A simple solution of copper sulphate, using 1 pound to 100 gallons of water, is frequently used for the final applications, but is much inferior to the Burgundy mixture.

SPRAYING.

SPRAYING APPARATUS.

The selection of a spraying outfit is a very important matter and should be carefully considered by anyone who is about to undertake this work. It will be found far better in the end to invest a larger amount at the start than to purchase a cheap outfit which may not be best adapted to the work and may prove a source of vexation, delay, and expense.

Good machines are frequently ruined in a few seasons by lack of proper care. It will be found a great saving of time and expense to wash out the spray tank, pump, and nozzles thoroughly after using and keep the machine under cover. The packing of the pump should also be looked after frequently.

The three most essential factors concerned in the operation of spraying are the power, the pump, and the nozzle.

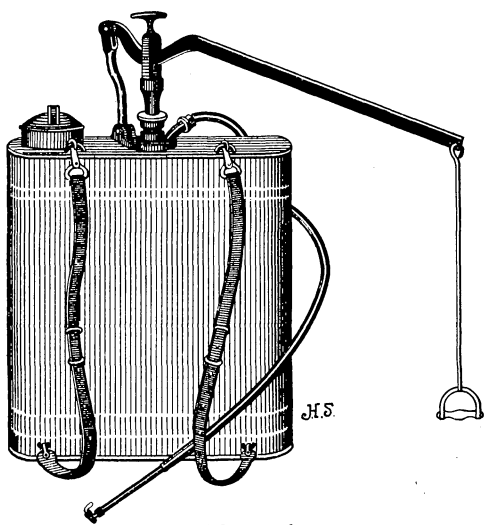

FIG. 23.—A knapsack sprayer.

Power.

Hand-power, horse-power, carbonic-acid gas, compressed air, and engines run by steam, gasoline, and kerosene are all used for spraying. In order to produce a satisfactory mist-like spray the power must be contant and sufficient to keep up the necessary pressure.

Hand-power.—Excellent work can be done by hand-power, using a knapsack or barrel pump (figs. 23, 24), but the time and labor required make it objectionable in large vineyards. In small vineyards it may be used to advantage.[a]

[a] For a general discussion of spraying machinery see Farmers' Bulletin 243, Fungicides and Their Use in Preventing Diseases of Fruits, by M. B. Waite.

Horse-power.—Used in connection with a geared sprayer, horse-power is in very general use in vineyards. There are a number of forms of these sprayers on the market, most of which are unsatisfactory, as it is not always possible to keep up sufficient and uniform pressure without driving so fast that the vines can not be properly covered with the mixture. One of these machines is shown in figure 25. This, with the addition of the two nozzles directed downward from above, does fairly good work.

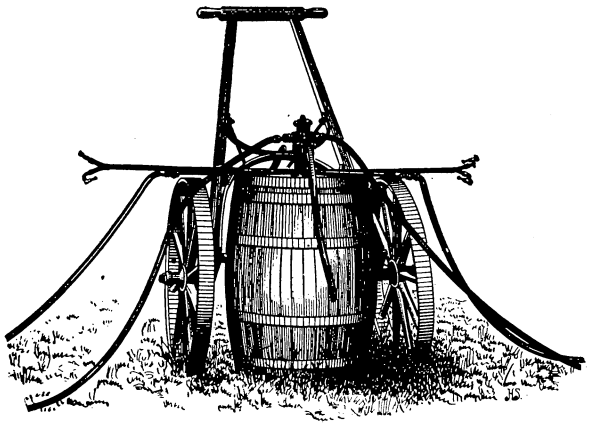

FIG. 24.—A barrel and cart spraying outfit.

Carbonic-acid gas furnishes excellent power and does entirely satisfactory work in spraying. The pressure can be easily controlled and there is no pump to get out of order. It is considered somewhat more expensive than horse-power or gasoline power, however, and unless one is so situated that the drums can be recharged promptly, serious delays may occur which will interfere with the success of the work. A gas spraying outfit is shown in figure 26. A smaller tank mounted on a two-wheeled cart is also used.

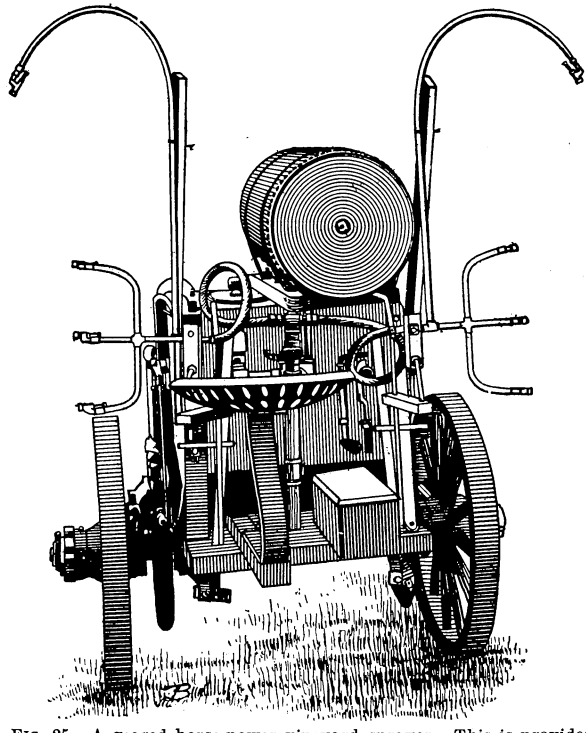

FIG. 25.—A geared horse-power vineyard sprayer. This is provided with a compressed air tank and an extra nozzle on each side directed downward in order to spray the tops of the vines.

Compressed air is used in the same way as gas (fig. 27). The air

is compressed by means of a stationary engine and air pump. Excellent work may be done with such a machine. The relative expense of this as compared with other forms of power has not, so far

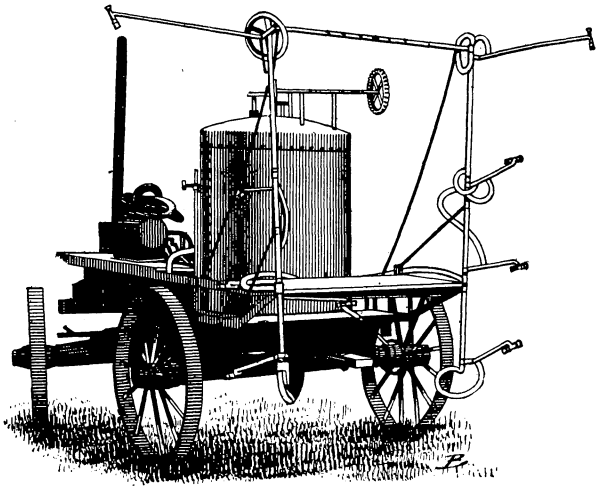

FIG. 26.—A carbonic-acid-gas sprayer.

as we know, been accurately determined. It is, however, preferred by some growers.

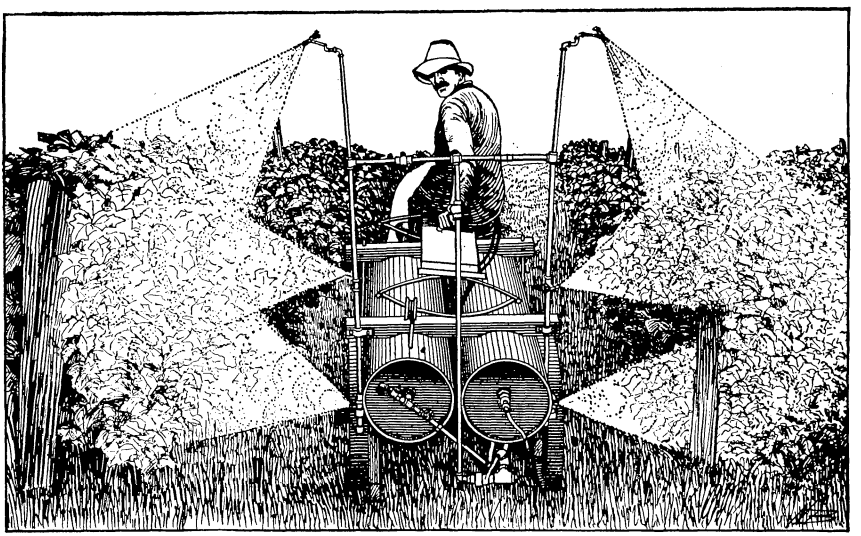

FIG. 27.—A compressed-air sprayer in operation.

Gasoline.—Steam engines are sometimes used, but they are usually found too bulky and heavy for vineyard work. Alcohol has not yet apparently been used in this connection. A cheap denatured

alcohol may perhaps eventually replace gasoline. At present, however, gasoline furnishes the most convenient and economical power. A compact and strong engine of two or three horsepower, with pump made especially for spraying purposes, will be found most

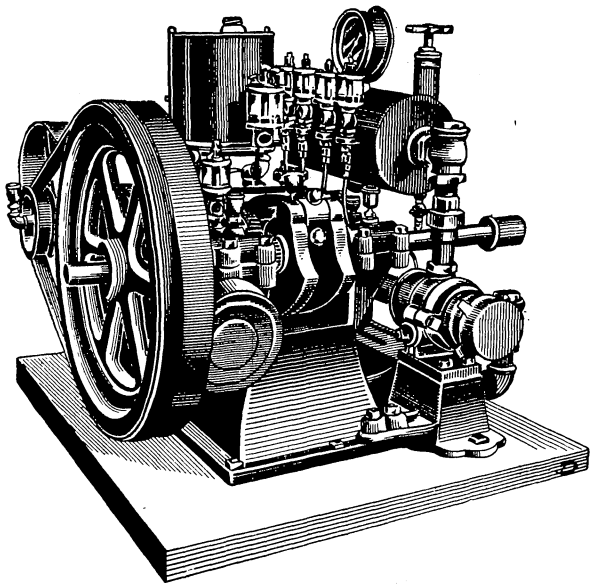

FIG. 28.—A gasoline engine and pump made especially for spraying.

satisfactory (fig. 28). Such an engine mounted upon a light handy wagon similar to that shown in figure 29, with a tank holding 100 to 150 gallons and fitted with adjustable rods and nozzles (fig. 30), would perhaps make the most efficient and economical outfit for

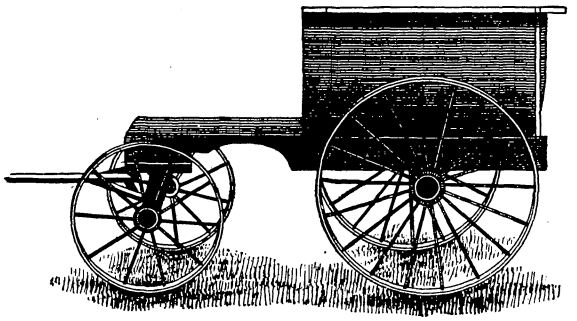

FIG. 29.—Wagon and tank adapted to vineyard spraying. A gasoline engine may be fitted in front and the upright adjustable rods and nozzles shown in figure 30 added.

extensive vineyard use. With such an outfit one may drive slowly and cover the vines and foliage thoroughly. If one has orchard fruit to spray, an engine is still more desirable. It may also be used for other purposes about a place.

Pumps.

The pump is a very important part of a spraying outfit. It should be strongly and carefully constructed and especially made for spraying purposes. For use with Bordeaux mixture all the working parts coming in contact with the mixture should be made of brass. Iron is acted upon by Bordeaux mixture and is finally destroyed. Leather valves should be avoided for the same reason. A good-sized air chamber is also an essential feature in connection with the pump, as it helps to maintain a uniform pressure.

Two of the styles of pumps in common use are shown in the accompanying illustrations (figs. 31, 32).

Nozzles.

Being supplied with satisfactory power and pump, the next important feature of the outfit is the spray nozzle. A nozzle of the Vermorel or cyclone type (see fig. 33), when properly made, will give a fine mist-like spray and is to be preferred to other types. It is to be regretted that most of the nozzles in general use, whether of this form or some other, are not made with sufficient care. The nozzles should be made of brass and the inlet chamber and the opening through the cap should be very smoothly and accurately drilled. The frequent use of a degorger will gradually wear the opening in the disk and make it irregular. For this reason interchangeable disks are desirable. These should be made of hardened brass, steel, or some other material which is neither attacked by the chemicals in the mixture nor easily injured by a degorger. Iron, zinc, and tin are worthless and should be carefully avoided. A poor nozzle wastes power and material and sprinkles the vines instead of spraying them, while the result of the work is not satisfactory. A properly made nozzle should give a fine mist-like spray with a minimum amount of pressure.

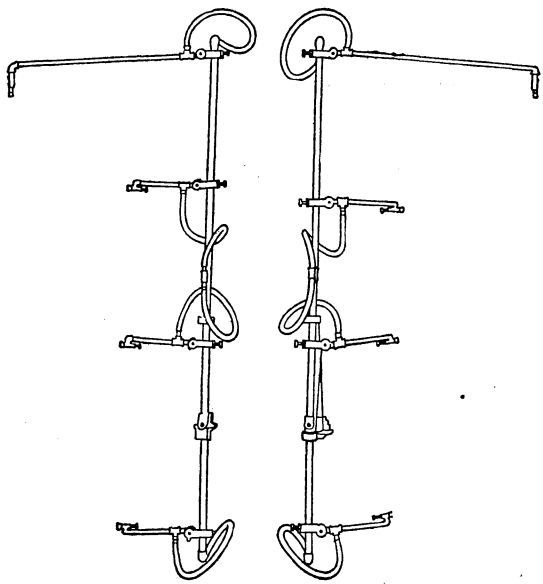

FIG. 30.—Adjustable rods and nozzles for vineyard spraying.

APPLICATION OF SPRAY MIXTURES.

Having a satisfactory outfit and the mixture properly prepared, there is still liability of failure unless the mixture is applied properly and at the proper times.

In spraying, the aim should be to cover as nearly as possible the entire surface of the vines, foliage, and fruit with the mixture, in order to destroy all the germs of the various parasites which may come in contact with the plant, and to destroy the insects which may feed upon the foliage, fruit, or buds.

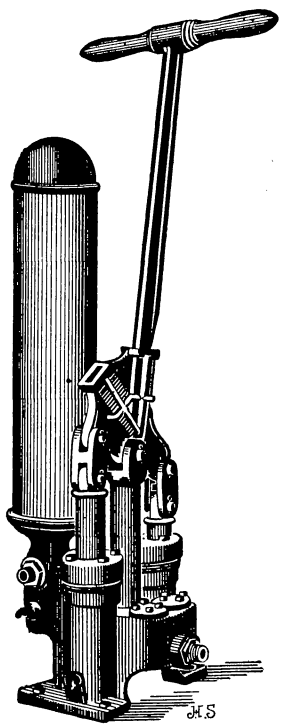

FIG. 31.—A large hand spray pump with double vertical cylinders for use with tank outfits.

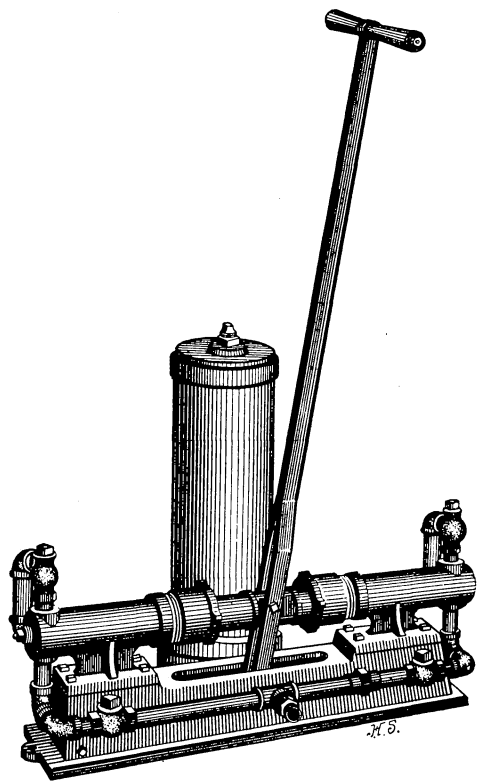

FIG. 32.—A large hand spray pump with double horizontal cylinders for use with tank outfits.

The accompanying illustrations (figs. 34 and 35) show two grape leaves to which Bordeaux mixture has been applied. Figure 34 shows a leaf properly sprayed. Figure 35 shows a leaf which has been sprinkled rather than sprayed. Too much of the mixture having been applied, it has run together in drops or fallen to the ground and been wasted. The leaf shown in figure 35 is, however, covered better than is generally the case in vineyard spraying. Thorough work is absolutely necessary if satisfactory results are to be secured. The nozzles should be carefully adjusted and directed, and should

also be watched to see that they do not clog. The rods with adjustable nozzles, such as shown in figure 30, have given best results. The team should be driven slowly and at the proper distance from the vines.

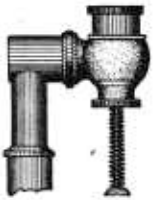

FIG. 33.—A vermorel spray nozzle.

Time of application.

First application.—In case fungous diseases are causing serious loss, or the vineyard has not been sprayed before, a thorough application of the strong Bordeaux mixture mentioned (6–3–50 formula) should be made just before the buds open. For the grape-growing regions of New York, Pennsylvania, Ohio, and Michigan this will usually be about May 1. If injury from the grapevine flea-beetle is anticipated, an arsenical should be added to the mixture.

Second application.—This should be made just before the blossoms begin to open, which will be about the 1st of June for the States mentioned. The ordinary Bordeaux mixture (5–5–50 furmula) should be used, and with an arsenical added the spray will be effective

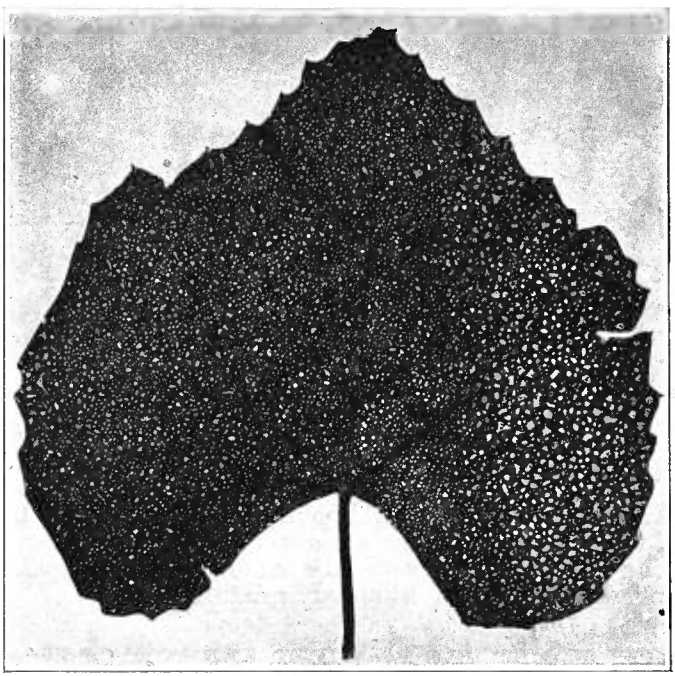

FIG. 34.—A grape leaf properly sprayed, showing the surface covered with minute drops of the Bordeaux mixture.

against the grapevine flea-beetle, the rose-chafer, grape curculio, and the first brood of the grape berry moth and the grape leaf-folder, respectively.

Third application.—This should be made as soon as the blossoms fall, using Bordeaux mixture as above and an arsenical to give

further protection against the insects mentioned and to poison the grape root-worm, the beetles of which are at this time just beginning to appear.

Fourth application.—This should be made within 10 days after the third application, using Bordeaux mixture as above and an arsenical. This and the preceding applications are especially important for the grape root-worm and the grape curculio, and will also afford further protection against the grape berry moth and the leaf-folder. For the insects first mentioned, it is very important that this application be delayed not longer than 10 days after the third.

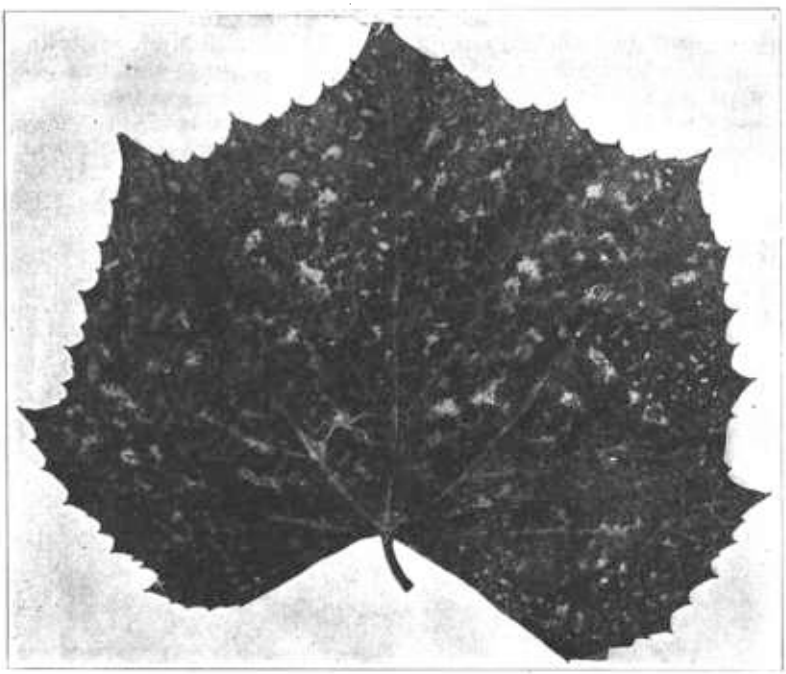

FIG. 35.—A grape leaf improperly sprayed. The mixture has been sprinkled upon the leaf instead of being sprayed in a fine mist, and the surface is not evenly and properly covered.

Fifth application.—This should be made two weeks after the fourth, using the Burgundy mixture recommended, and no arsenical.

Sixth application.—This should be made about two weeks after the last application, using the Burgundy mixture only.

QUANTITY OF MIXTURE REQUIRED AND COST OF TREATMENT.

One hundred and twenty-five gallons of Bordeaux mixture is usually sufficient for a single application to an acre of vines of average size. Where the vines are large and the foliage dense, as much as 150 gallons may be necessary for a thorough application. It will be better to use too much of the mixture than too little. The cost for labor and material will vary from $12 to $15 per acre for six applications, including an arsenical poison for biting insects.